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(54)Title of the Invention

INVERSED F ANTENNA, FEED METHOD THEREFOR, AND ANTENNA ADJUSTING METHOD

(57) [Abstract] (amended)

[Object] To provide an inversed F antenna and a feed method therefor in which the characteristic impedance of a feed line matches the input impedance of the antenna in a wide range of a frequency band.

[Solution] There is provided an inversed F antenna including a radiation conductor 202, a ground conductor 204 which is arranged so as to face the radiation conductor 202 while leaving a space therebetween, a short circuit (short) plate 206, as short circuit means, through which the radiation conductor 202 is coupled to the ground conductor 204, and a feed conductor 210 which is provided to extend within a space between the radiation conductor 202 and the

ground conductor 204 and to which a feed line (feed pin) 208 is coupled, wherein power is fed from the feed line (feed pin) 208 to the radiation conductor 202 through the feed conductor 210.

[Scope of Claim]

[Claim 1] An inversed F antenna comprising:

antenna elements made of conductor;

a ground conductor which is arranged so as to face the antenna elements while leaving spaces therebetween;

short circuit means through which the antenna elements are coupled to the ground conductor; and

a feed line which feeds power to the antenna elements, wherein

the antenna elements are configured as a double structure in which a feed conductor and a radiation conductor are separately provided, and power is fed from the feed line to the radiation conductor through the feed conductor without feeding directly from the feed line to the radiation conductor.

[Claim 2] An inversed F antenna comprising:

a radiation conductor;

a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween;

short circuit means through which the radiation conductor is coupled to the ground conductor; and

a feed line which feeds power to the radiation conductor, wherein

a feed conductor which is provided to extend within a space between the radiation conductor and the ground

conductor and to which the feed line is coupled is further provided, and power is fed to the radiation conductor through the feed conductor.

[Claim 3] The inversed F antenna according to claim 2, wherein

the feed conductor is coupled to the short circuit means, and is provided to extend within the space between the radiation conductor and the ground conductor from the short circuit means.

[Claim 4] The inversed F antenna according to claim 2, wherein

the feed conductor is apart from the short circuit means, and is provided to extend within the space between the radiation conductor and the ground conductor.

[Claim 5] The inversed F antenna according to claims 1 to 4, wherein

the radiation conductor is formed in a plate shape and the feed conductor is formed in a plate shape while having an area overlapped with the radiation conductor and leaving a predetermined space therebetween.

[Claim 6] The inversed F antenna according to claims 1 to 5, wherein

at least the radiation conductor, the ground conductor, and the feed conductor are formed on a resin substrate as a conductor pattern.

[Claim 7] The inversed F antenna according to claim 6, wherein

the inversed F antenna is configured as a three-layer resin substrate which includes the radiation conductor as a first layer pattern, the feed conductor as a second layer pattern which faces the radiation conductor to sandwich a first resin portion, and the ground conductor as a third layer pattern which faces the feed conductor to sandwich a second resin portion, and the feed line through which the ground conductor is coupled to the feed conductor is configured as a through-hole.

[Claim 8] The inversed F antenna according to claim 7, wherein

the short circuit means which short-circuits the radiation co1nductor and the ground conductor is formed by a short circuit conductor formed on a side face of the resin substrate.

[Claim 9] The inversed F antenna according to claim 7, wherein

the short circuit means which short-circuits the radiation co1nductor and the ground conductor is configured as a through-hole.

[Claim 10] The inversed F antenna according to claims 1 to 5, wherein

at least the radiation conductor, the ground

conductor, and the feed conductor are formed on a ceramic substrate as a conductor pattern.

[Claim 11] The inversed F antenna according to claim 10, wherein

the inversed F antenna is configured as a three-layer ceramic substrate which includes the radiation conductor as a first layer pattern, the feed conductor as a second layer pattern which faces the radiation conductor to sandwich a first ceramic portion, and the ground conductor as a third layer pattern which faces the feed conductor to sandwich a second ceramic portion, and the feed line through which the ground conductor is coupled to the feed conductor is configured as a through-hole.

[Claim 12] The inversed F antenna according to claim 11, wherein

the short circuit means which short-circuits the radiation co1nductor and the ground conductor is formed by a short circuit conductor formed on a side face of the ceramic substrate.

[Claim 13] The inversed F antenna according to claim 11, wherein

the short circuit means which short-circuits the radiation co1nductor and the ground conductor is configured as a through-hole.

[Claim 14] A feed method in an inversed F antenna, the

antenna comprising:

a radiation conductor;

a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween;

short circuit means through which the radiation conductor is coupled to the ground conductor; and

a feed line which feeds power to the radiation conductor, wherein

a feed conductor is further provided to extend within a space between the radiation conductor and the ground conductor, and power is fed from the feed line to the radiation conductor through the feed conductor by coupling the feed line to the feed conductor.

[Claim 15]An antenna adjusting method in an inversed F antenna, the antenna comprising:

a radiation conductor;

a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween;

short circuit means through which the radiation conductor is coupled to the ground conductor; and

a feed line which feeds power to the radiation conductor, wherein

a feed conductor is provided to extend within a space between the radiation conductor and the ground conductor, the feed line is coupled to the feed conductor to feed

power to the radiation conductor through the feed conductor, and antenna adjustment is performed by changing the shape of the radiation conductor.

[Detailed Description of the Invention]

[0001]

[Technical Field Pertinent to Invention]

The present invention relates to an inversed F antenna, a feed method therefor, and an antenna adjusting method such as adjustment of its resonance frequency. The present invention relates, particularly, to a technique for matching the impedance of the antenna with that of a feed line in an inversed F antenna incorporated into a mobile communication device, an information device, a home appliance, or the like.

[0002]

[Prior Art]

As a small-sized antenna incorporated into a mobile communication device, or the like such as a built-in antenna of a mobile phone, there has been known an inversed F antenna from the past. The inversed F antenna is configured in such a manner that an L-shape antenna formed by bending a tip end of a $\lambda/4$ monopole antenna is manufactured as a low-profile antenna and a short circuit portion is provided around a feed point position to easily obtain impedance matching at the feed point. In order to

easily obtain the impedance matching by further making the linear-shape inversed F antenna low profile and by broadening the bandwidth, a horizontal portion with respect to the bent ground plate is formed in a plate shape. The antenna having this shape is called a plate-shape inversed F antenna.

[0003]

An example of a conventional inversed F antenna is shown in Fig. 1. Fig. 1 shows a basic configuration of the plate-shape inversed F antenna which is widely well known. Specifically, an inversed F antenna 100 includes, as shown in Fig. 1, a rectangular radiation electrode (radiation conductor) 102 made of conductive metal such as sheet metal, a ground plate (ground conductor) 104 which is arranged to face the radiation conductor 102 while leaving a space therebetween, a short circuit (short) plate 106, as short circuit means, through which one end of the radiation electrode 102 is coupled to the ground plate 104, and a feed line 108 which feeds power to the radiation electrode 102. The power feeding to the radiation electrode 102 is performed through a coaxial cable configuring the feed line 108 from, for example, a back surface of the ground plate 104, and an outer conductor 108a of the coaxial cable is coupled to the ground plate 104. A core (or feed pin) 108b of the coaxial cable is coupled to the rectangular

radiation electrode 102 at an appropriate position so as to match the characteristic impedance of the coaxial cable with the input impedance of the inversed F antenna 100. Specifically, the core (or feed pin) 108b of the coaxial cable configuring the feed line 108 is directly attached to the radiation electrode 102 for power feeding in the conventional inversed F antenna 100 as shown in Fig. 1.

[0004]

[Problem to be solved by the Invention]

In recent years, mobile communications using mobile phones and the like have been attracting lots of attention, and along with this, further downsizing of mobile terminal devices has been required. With the widespread of mobile terminal devices, an antenna has been required to have broader band characteristics due to the necessity of broadening the frequency band of communications to expand the communication capacity. On the other hand, there is a common problem that if an antenna is more downsized, it becomes more difficult to obtain impedance matching with a feed line.

[0005]

As described above, the inversed F antenna is used as a built-in antenna of a mobile phone, or the like in many cases, and is regarded as an antenna for which downsizing is especially required. Specifications of mobile phones

variously differ depending on manufacturers, and surrounding environments where the inversed F antenna is built in differ from each other in many cases. Further, the inversed F antenna is used while being mounted in various information devices, home appliances, or the like, other than mobile phones.

[0006]

As described above, since the inversed F antenna is used while being mounted in various devices, if the frequency band where the input impedance of the antenna matches the characteristic impedance of a feed line is narrow, the antenna characteristics are changed and it is difficult to use in the case where the mounted state is different.

[0007]

For example, in the case where the same configuration as that of the conventional inversed F antenna 100 shown in Fig. 1 is formed on a substrate made of ceramic or resin (not shown), the feed line (feed pin) 108 and the short circuit (short) plate 106 become closer to each other on the substrate, and it is difficult to match the characteristic impedance of the feed line with the input impedance of the antenna due to the inductance of the feed line (feed pin) 108. Further, the frequency band in which the impedance matching can be obtained becomes narrower.

Therefore, in the case where the same configuration as that of the conventional inversed F antenna 100 is formed on a substrate made of ceramic or resin while being adjusted in a certain normal state and is used in a communication device in a mounted state, difference in electric characteristics around the antenna such as the thickness of the substrate and the mounted position causes deterioration of the matching degree of the antenna and the feed system due to the narrow band of impedance matching as described above, resulting in significant decrease in sensitivity as an antenna.

[0008]

Specifically, in the case where power is fed using, for example, a 50Ω feed line (feed line with a characteristic impedance of 50Ω) in the conventional inversed F antenna 100 shown in Fig. 1, a feed position (a position at which the feed line (feed pin) 108 is coupled to the radiation electrode 102) where the impedance matching can be obtained is limited to a position closer to the short circuit (short) plate 106. In other words, it is difficult to obtain the impedance matching. Especially, if the inversed F antenna is further downsized, this tendency becomes strong.

[0009]

As described in, for example, Japanese Unexamined

Patent Application publication No. H9-98015, while the same problem that it is difficult to obtain impedance matching as a result of making the feed pin closer to the short pin along with downsizing in a patch antenna is recognized, there is an example of disclosing a configuration (which is not for the inversed F antenna) for solving the problem. However, in the conventional inversed F antenna, an effective solution has not been proposed yet in order to solve the problem. Accordingly, even in the case where the conventional inversed F antenna is further downsized and low-profiled, an inversed F antenna with a novel configuration which can obtain the impedance matching in a broad bandwidth is strongly required as similar to the relatively-large conventional inversed F antenna.

[0010]

On the other hand, according to the nature of an antenna which radiates radio waves into space and receives radio waves flying through space, the antenna itself and the space around the antenna affect the characteristics of the antenna. Therefore, even when the inversed F antenna is incorporated into a device such as a mobile phone, if there is an object around the antenna, current flows in the object, resulting in different characteristics from the antenna alone. Therefore, design of the inversed F antenna to be incorporated into the device has to be carried out

while regarding the inversed F antenna and the object closer to the inversed F antenna as one antenna system.

[0011]

However, if a device such as a mobile phone is developed, a cover or the like covering the inversed F antenna is usually finished in a later stage of the development. Accordingly, if the design of the inversed F antenna is started after the final usage condition is determined in the later stage, the development of the antenna does not possibly meet the deadline due to the relation with the development/design period of the whole device, and it is difficult because of time. Therefore, the antenna incorporated into a device such as a mobile phone is required for the following two features: the antenna itself is hardly affected by the surrounding environments, and is capable of coping with the electric characteristics around the antenna in various mounted states; and even after a mounted state is determined, it is possible to easily adjust the antenna such as shifting of the frequency band.

[0012]

An object of the present invention is to provide an inversed F antenna and a feed method therefor in which the characteristic impedance of a feed line matches the input impedance of the antenna in a wide range of a frequency

band and which are capable of coping with the electric characteristics around the antenna in various mounted states.

[0013]

Further, another object of the present invention is to provide an inversed F antenna and an adjusting method therefor by which antenna adjustment such as shifting of a frequency band can be easily performed.

[0014]

[Means for Solving the Problem]

In order to achieve the above-described object, an inversed F antenna according to the present invention is configured as a double structure in which conductors (electrodes) as antenna elements which are arranged while leaving spaces with a ground conductor and one ends of which configure open ends are separately provided as a feed conductor (electrode) and a radiation conductor (electrode), and power is fed to the radiation conductor (electrode) through the feed conductor (electrode) without directly feeding from a feed line to the radiation conductor.

[0015]

Accordingly, even in the case where the inversed F antenna is further downsized and low-profiled as compared to the conventional inversed F antenna, the impedance matching between the antenna and the feed line can be

obtained in a broad bandwidth as similar to the relatively-large conventional inversed F antenna. Thus, it is possible to obtain an inversed F antenna and a feed method therefor which are capable of coping with the electric characteristics around the antenna in various mounted states.

[0016]

Further, by changing the shape of the radiation conductor in the above-described double structure, antenna adjustment such as resonance frequency adjustment, multiple resonances, and downsizing is performed.

[0017]

Accordingly, it is possible to perform the antenna adjustment without losing the impedance matching between the antenna and the feed line.

[0018]

According to an aspect of the present invention, it is possible to obtain an inversed F antenna including: antenna elements made of conductor; a ground conductor which is arranged so as to face the antenna elements while leaving spaces therebetween; short circuit means through which the antenna elements are coupled to the ground conductor; and a feed line which feeds power to the antenna elements, wherein the antenna elements are configured as a double structure in which a feed conductor and a radiation

conductor are separately provided, and power is fed from the feed line to the radiation conductor through the feed conductor without feeding directly from the feed line to the radiation conductor.

[0019]

The "ground conductor" used herein may not be a ground of the antenna itself. Specifically, the ground conductor includes a ground substrate in the case where the inversed F antenna itself does not include a ground, and a substrate on which an antenna is mounted, such as a substrate for mounting an RF circuit on which a transmission/reception circuit is arranged in a mobile terminal device and a substrate for mounting a baseband circuit coupled to a terminal operation key serves as a ground.

[0020]

Here, the "feed conductor" is a constituent element which is separately provided from the "feed line", and does not include a conductor portion configuring the "feed line", for example, an inner conductor of the coaxial cable. It should be noted that the "feed conductor" may include a case in which the "feed line" and the "feed conductor" are integrally formed on a substrate made of resin or ceramic as a conductor pattern which is to be described later. Further, it is preferable that the "feed conductor" is in

parallel to the "radiation conductor". However, the "feed conductor" may not be in parallel to the "radiation conductor". It is advantageous in manufacturing if the "feed conductor" is in parallel to the "radiation conductor". Further, it is preferable that the "feed conductor" is formed in a plate shape. However, the "feed conductor" may be formed in not a plate shape but a linear (rod) shape.

[0021]

Further, according to another aspect of the present invention, it is possible to obtain an inversed F antenna including: a radiation conductor; a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween; short circuit means through which the radiation conductor is coupled to the ground conductor; and a feed line which feeds power to the radiation conductor, wherein a feed conductor which is provided to extend within a space between the radiation conductor and the ground conductor and to which the feed line is coupled is further provided, and power is fed to the radiation conductor through the feed conductor.

[0022]

The feed conductor may be coupled to the short circuit means, and may be provided to extend within the space between the radiation conductor and the ground

conductor from the short circuit means. On the other hand, the feed conductor may be apart from the short circuit means, and may be provided to extend within the space between the radiation conductor and the ground conductor.

[0023]

Further, it is desirable that the radiation conductor is formed in a plate shape and the feed conductor is formed in a plate shape while having an area overlapped with the radiation conductor and leaving a predetermined space therebetween.

[0024]

Further, at least the radiation conductor, the ground conductor, and the feed conductor are formed on a resin or ceramic substrate as a conductor pattern.

[0025]

Further, the inversed F antenna is configured as a three-layer resin or ceramic substrate which includes the radiation conductor as a first layer pattern, the feed conductor as a second layer pattern which faces the radiation conductor to sandwich a first resin or ceramic portion, and the ground conductor as a third layer pattern which faces the feed conductor to sandwich a second resin or ceramic portion, and the feed line through which the ground conductor is coupled to the feed conductor is configured as a through-hole.

[0026]

The short circuit means which short-circuits the radiation co1nductor and the ground conductor may be formed by a short circuit conductor formed on a side face of the resin or ceramic substrate. Alternatively, the short circuit means which short-circuits the radiation co1nductor and the ground conductor may be configured as a through-hole.

[0027]

In consideration of easiness of manufacturing, it is preferable that the position (feed position) where the "feed line" is coupled to the "feed conductor" is an end portion (edge portion) in the width direction of the "feed conductor", but may be a center portion in the width direction of the "feed conductor".

[0028]

Further, according to still another aspect of the present invention, it is possible to obtain a feed method in an inversed F antenna, the antenna including: a radiation conductor; a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween; short circuit means through which the radiation conductor is coupled to the ground conductor; and a feed line which feeds power to the radiation conductor, wherein a feed conductor is further provided to extend

within a space between the radiation conductor and the ground conductor, and power is fed from the feed line to the radiation conductor through the feed conductor by coupling the feed line to the feed conductor.

[0029]

Further, according to still another aspect of the present invention, it is possible to obtain an antenna adjusting method in an inversed F antenna, the antenna including: a radiation conductor; a ground conductor which is arranged so as to face the radiation conductor while leaving a space therebetween; short circuit means through which the radiation conductor is coupled to the ground conductor; and a feed line which feeds power to the radiation conductor, wherein a feed conductor is provided to extend within a space between the radiation conductor and the ground conductor, the feed line is coupled to the feed conductor to feed power to the radiation conductor through the feed conductor, and antenna adjustment is performed by changing the shape of the radiation conductor.

[0030]

Here, the "changing of the shape of the radiation conductor" includes, for example, the following all steps: making a cut in the radiation conductor, changing the length thereof, or making a slot for adjustment of the resonance frequency; providing a perturbation element to

the radiation conductor, or dividing the radiation conductor into two or more and changing their lengths for multiple resonances; and bending a tip end of the radiation conductor to add capacity (tip-end condenser loading) for downsizing. In the meantime, the "antenna adjustment" includes all the cases of adjusting the characteristics or shape of the antenna for adjustment of the resonance frequency, multiple resonances, and downsizing.

[0031]

[Embodiment of the Invention]

Hereinafter, embodiments of the present invention will be described in more detail with reference to the drawings. Fig. 2(A) is a perspective view showing a basic configuration of an inverted F antenna according to a first embodiment of the present invention, and Fig. 2(B) is a side view thereof. As shown in Figs. 2(A) and 2(B), an inversed F antenna 200 includes antenna elements (202 and 210) made of conductor, a ground conductor (204) which is arranged so as to face the antenna elements (202 and 210) while leaving spaces therebetween, short circuit means (206) through which the antenna elements (202 and 210) are coupled to the ground conductor (204), and a feed line (208) which feeds power to the antenna elements (202 and 210). The antenna elements (202 and 210) are configured as a double structure in which a feed conductor (210) and a

radiation conductor (202) are separately provided. The inversed F antenna 200 has a function of feeding power from the feed line (208) to the radiation conductor (202) through the feed conductor (210) without feeding directly from the feed line (208) to the radiation conductor (202).

[0032]

Specifically, as shown in Figs. 2(A) and 2(B), the inversed F antenna 200 includes the radiation conductor 202, the ground conductor 204 which is arranged so as to face the radiation conductor 202 while leaving a space therebetween, a short circuit (short) plate 206, as short circuit means, through which the radiation conductor 202 is coupled to the ground conductor 204, and the feed conductor 210 which is provided to extend within a space between the radiation conductor 202 and the ground conductor 204 and to which the feed line (feed pin) 208 is coupled. The inversed F antenna 200 has a configuration in which power is fed from the feed line (feed pin) 208 to the radiation conductor 202 through the feed conductor 210. The power feeding from the feed line (feed pin) 208 to the feed conductor 210 is performed through a coaxial cable configuring the feed line 208 from a back surface of the ground conductor 204. An outer conductor 208a of the coaxial cable is coupled to the ground conductor 204, and a core (or feed pin) 208b of the coaxial cable is coupled to

the feed conductor 210 at an appropriate position so as to match the characteristic impedance of the coaxial cable with the input impedance of the inversed F antenna 200. Specifically, in the inversed F antenna 200, the core (or feed pin) 208b of the coaxial cable configuring the feed line 208 is directly attached to not the radiation conductor 202 but the feed conductor 210, as shown in Figs. 2(A) and 2(B), and power is fed to the radiation conductor 202 through the feed conductor 210.

[0033]

In the embodiment, the feed conductor 210 which is coupled to the short circuit (short) plate 206 is provided to extend within the space between the radiation conductor 202 and the ground conductor 204 from the short circuit (short) plate 206 as shown in Fig. 2(B).

[0034]

Further, the radiation conductor 202 is formed in a plate shape in the embodiment. The feed conductor 210 is also formed in a plate shape while having an area overlapped with the radiation conductor 202 and leaving a predetermined space therebetween.

[0035]

As a modified example, although not shown in the drawing, the radiation conductor 202 may be formed in a plate shape, and the feed conductor 210 may be configured

in a rod shape or a linear shape. Further, each of the radiation conductor 202 and the feed conductor 210 may be configured in a rod shape or a linear shape. Furthermore, the short circuit (short) plate 206 may be configured in a rod shape or a linear shape as a short circuit conductor. In this case, the antenna is configured as not a plate-shape inversed F antenna but a linear-shape inversed F antenna. Even in this case, effects of the plate-shape inversed F antenna according to the embodiment to be described later can be similarly obtained.

[0036]

Fig. 3(A) is a view of a radiation electrode 102 of a conventional inversed F antenna 100 viewed from the upper side. Fig. 3(B) is a view of the feed conductor 210 of the inversed F antenna 200 according to the embodiment viewed from the upper side, and the radiation conductor 202 is shown by the dotted line.

[0037]

In the embodiment, the impedance of the conventional inversed F antenna 100 shown in Fig. 1 and that of the inversed F antenna 200 according to the embodiment shown in Fig. 2 viewed from the feed system are calculated by an electromagnetic simulator for comparison.

[0038]

Here, the conventional inversed F antenna 100 and the

inversed F antenna 200 according to the embodiment, each having the same volume of 15mm × 3mm × 3mm are configured on infinite ground planes, and each of feed points 111 and 213 is changed to observe a return loss viewed from the feed system. Each antenna is configured by a conductor plate with a conductivity of 4.9 × 107 and a thickness of 18μm. The position of each of the short circuit (short) plates 106 and 206 is assumed as y=0 to obtain a feed point position where impedance matching can be obtained, and the changes of the return loss are observed when the feed point position is shifted by ±0.5mm from the original position. First, when the feed points are set to y=1.5mm in the conventional inversed F antenna 100 and y=3.5mm in the inversed F antenna 200 according to the embodiment, it is possible to match the characteristic impedance of the feed line with the impedance of the antenna. Accordingly, the feed point position in the inversed F antenna 200 according to the embodiment is further from the short circuit (short) plate 206 as compared to that in the conventional inversed F antenna 100. Fig. 4 shows a smith chart in which the feed points are offset by ±0.5mm after the impedance matching is obtained in the conventional inversed F antenna 100, and Fig. 5 shows a smith chart in which the feed points are offset by ±0.5mm after the impedance matching is obtained in the inversed F antenna 200 according to the embodiment.

It should be noted that the frequency ranges from 3 to 5GHz, and the resonance frequency of each antenna is 4.25GHz.

[0039]

Each of the feed lines 108 and 208 is a 50Ω feed line (feed line with a characteristic impedance of 50Ω) as described above, and 50Ω is located at the center of the circle. The circular points, rectangular points, and rhombic points plotted on each smith chart are obtained by plotting the frequency changes of the impedance of the antenna. Accordingly, the plotted points (arc obtained by connecting the plotted points) which are not shifted from 50Ω as the center of the smith chart are preferable in characteristics.

[0040]

In the conventional example, when the feed point positions are offset from the reference position by ±0.5mm, the plotted points (arc obtained by connecting the plotted points) are largely shifted from 50Ω as the center of the smith chart. On the contrary, when the feed point positions are similarly shifted from the reference position by 0.5mm in the embodiment, the plotted points are not largely shifted from 50Ω as the center of the smith chart.

[0041]

From Figs. 4 and 5, it was found that when the feed point was offset, fluctuation of the impedance was small in

the inversed F antenna 200 according to the embodiment. In order to consider the cause, the inventors observed, at first, the standing wave distribution of the conventional inversed F antenna 100 shown in Figs. 1 and 3(A) using the electromagnetic simulator. In the conventional inversed F antenna 100, standing waves of current rose around both edges 102a and 102b which were sides parallel to the y-axis on the radiation electrode 102 shown in Fig. 3(A), and the standing waves became a radiation source. In the conventional inversed F antenna 100 shown in each of Figs. 1 and 3(A), it was confirmed that the standing waves which rose around the both edges 102a and 102b which were sides parallel to the y-axis on the radiation electrode 102 were asymmetric. It is conceivable that the feed point 111 is located at the edge portion where the standing waves rise, so that the standing waves rising around the edge 102b where the feed point 111 is located are disturbed by the feed system. It can be assumed that such disturbance caused by direct feeding to the radiation electrode 102 contributes to a narrow range of the feed position where the impedance matching can be obtained, and decreases the radiation efficiency of the antenna. Especially, in the case where the inversed F antenna 100 is further downsized, the size of the feed system can not be disregarded as compared to the size of the antenna element itself

configured by the radiation electrode 102, so that it can be predicted that the effect caused by mutual coupling of the feed system and the antenna element becomes large.

[0042]

The inventors observed next the standing wave distribution of the inversed F antenna 200 according to the embodiment similarly using the electromagnetic simulator. In the inversed F antenna 200 according to the embodiment, as similar to the conventional inversed F antenna 100, the standing waves of current rose around both edges 202a and 202b which were sides parallel to the y-axis on the radiation conductor 202 shown by the solid line in Fig. 2 or by the dotted line in Fig. 3(B), and the standing waves become a radiation source. It was confirmed that the standing waves which rose around the both edges 202a and 202b which were sides parallel to the y-axis on the radiation conductor 202 shown in each of Fig. 2 and Fig. 3(B) were symmetric.

[0043]

It can be assumed that although the feed point 213 is located at an edge 210b of the feed conductor 210, power is fed not directly to the radiation conductor 202 but through the feed conductor 210, so that the standing waves that rise around the both edges 202a and 202b which are sides parallel to the y-axis on the radiation conductor 202 are

relatively free from disturbance in power feeding. It is conceivable that such less disturbance caused by direct feeding to the radiation conductor 202 contributes to a wider range of the feed position where the impedance matching can be obtained.

[0044]

Fig. 6(A) is a perspective view showing a basic configuration of an inversed F antenna according to a second embodiment of the present invention, and Fig. 6(B) is a side view thereof. The basic configuration of an inversed F antenna 300 and that of the inversed F antenna 200 shown in Figs. 2(A) and 2(B) are substantially the same, but are different from each other in that a feed conductor 310 is not coupled to the short circuit (short) plate 206. Specifically, the feed conductor 310 is provided to extend within a space between the radiation conductor 202 and the ground conductor 204 while being apart from the short circuit (short) plate 206. The inversed F antenna 300 having such a configuration also exhibits the same effect as the inversed F antenna 200 shown in Figs. 2(A) and 2(B). Since the feed conductor 310 is not coupled to the short circuit (short) plate 206 in the inversed F antenna 300 according to the embodiment, it is necessary to insert and fix a spacer 330 made of insulator between the ground conductor 204 and the feed conductor 310 as shown by the

dotted line in Fig. 6(B) in order to support the feed conductor 310.

[0045]

Further, the radiation conductor 202 is formed in a plate shape even in the embodiment. The feed conductor 310 is also formed in a plate shape while having an area overlapped with the radiation conductor 202 and leaving a predetermined space therebetween.

[0046]

Fig. 7 is a perspective view showing a basic configuration of an inversed F antenna according to a third embodiment of the present invention. The basic constituent elements of an inversed F antenna 400 and those of the inversed antenna 200 shown in Figs. 2(A) and 2(B) are substantially the same, but are different from each other in that the inversed F antenna 400 is formed on a resin substrate.

[0047]

Specifically, as similar to the inversed F antenna 200 as shown in Figs. 2(A) and 2(B), the inversed F antenna 400 includes, as shown in Fig. 7, a radiation conductor 402, a ground conductor 404 which is arranged so as to face the radiation conductor 402 while leaving a space therebetween, a short circuit conductor 406, as short circuit means, through which the radiation conductor 402 is coupled to the

ground conductor 404, and a feed conductor 410 which is provided to extend within a space between the radiation conductor 402 and the ground cnductor404 and to which a feed line 408 is coupled. The inversed F antenna 400 has a configuration in which power is fed from the feed line 408 to the radiation conductor 402 through the feed conductor 410. The radiation conductor 402, the ground conductor 404, the short circuit conductor 406, the feed conductor 410, and a feed line 408L configuring a part of the feed line 408 are formed on, for example, a surface 445 of a phenol resin substrate 440. These are copper-clad portions of the phenol resin substrate 440, and etching is performed so as to leave these portions when manufacturing. An outer conductor 408a of a coaxial cable configuring the feed line 408 is coupled to the ground conductor 404, the power feeding from the feed line 408 to the feed conductor 410 is performed by mutually coupling a core 408b of the coaxial cable to the feed line 408L.

[0048]

The inversed F antenna 400 having such a configuration exhibits the same effect as the inversed F antenna 20 shown in Figs. 2(A) and 2(B). It should be noted that it is necessary that at least the radiation conductor 402, the ground conductor 404, and the feed conductor 410 are formed on the resin substrate as a

conductor pattern. Further, the above-described constituent elements are formed only on the surface 445 of the phenol resin substrate 440 in the embodiment. However, a part of the constituent elements may be formed on a back surface 447.

[0049]

As a modified example, it is conceivable that an inversed F antenna similar to the above is formed on a ceramic substrate and exhibits the same effect as the inversed F antenna 400 formed on the resin substrate. It should be noted that it is necessary that at least the radiation conductor, the ground conductor, and the feed conductor are formed on the ceramic substrate as a conductor pattern.

[0050]

Fig. 8 is a perspective view showing a basic configuration of an inversed F antenna according to a fourth embodiment of the present invention. An inversed F antenna 500 and the inversed F antenna 400 shown in Fig. 7 are the same in that they are formed on the resin substrate, but are different from each other in that the inversed F antenna 500 is formed on a multilayer resin substrate.

[0051]

Specifically, the inversed F antenna 500 includes, as shown in Fig. 8, a radiation conductor 502, a ground

conductor 504 which is arranged so as to face the radiation conductor 502 while leaving a space therebetween, a short circuit conductor 506, as short circuit means, through which the radiation conductor 502 is coupled to the ground conductor 504, and a feed conductor 510 which is provided to extend within a space between the radiation conductor 502 and the ground conductor 504 and to which a feed line 508 is coupled. The inversed F antenna 500 has a configuration in which power is fed from the feed line 508 to the radiation conductor 502 through the feed conductor 510. Three layers of the radiation conductor 502, the ground conductor 504, and the feed conductor 510 are formed on a resin substrate 550.

[0052]

As described above, the inversed F antenna 500 is configured as a three-layer resin substrate in the embodiment. As shown in Fig. 8, as a first layer pattern, the radiation conductor 502 and a resin portion 503 are sandwiched; as a second layer pattern, the feed conductor 510 and a resin portion 505 are sandwiched; and as a third layer pattern, the ground conductor 504 is formed. In addition, as means for short-circuiting the radiation conductor 502, the feed conductor 510, and the ground conductor 504, the short circuit conductor 506 is formed on a side face of the resin substrate 550. Further, the feed

line 508 through which the ground conductor 504 is coupled to the feed conductor 510 is configured as a semi-through-hole. The resin substrate 550 is made of, for example, phenol resin, and the radiation conductor 502, the ground conductor 504, the short circuit conductor 506, and the feed conductor 510 are manufactured by copper clad.

[0053]

The inversed F antenna 500 having such a configuration exhibits the same effect as the inversed F antenna 200 shown in Figs. 2(A) and 2(B). As a modified example of the embodiment, although not shown in the drawing, the short circuit conductor (506) may be configured as an elongate through-hole or a through-hole, or a semi-through-hole formed by cutting each hole into half.

[0054]

Fig. 9 is a perspective view showing a basic configuration of an inversed F antenna according to a fifth embodiment of the present invention. An inversed F antenna 600 and the inversed F antenna 500 shown in Fig. 8 are the same in that they are formed on the multilayer resin substrate, but are different from each other in that the inversed F antenna 600 is formed on a multilayer ceramic substrate.

[0055]

Specifically, the inversed F antenna 600 includes, as shown in Fig. 9, a radiation conductor 602, a ground conductor 604 which is arranged so as to face the radiation conductor 602 while leaving a space therebetween, a short circuit conductor 606, as short circuit means, through which the radiation conductor 602 is coupled to the ground conductor 604, and a feed conductor 610 which is provided to extend within a space between the radiation conductor 602 and the ground conductor 604 and to which a feed line 608 is coupled. The inversed F antenna 600 has a configuration in which power is fed from the feed line 608 to the radiation conductor 602 through the feed conductor 610. Three layers of the radiation conductor 602, the ground conductor 604, and the feed conductor 610 are formed on a ceramic substrate 650.

[0056]

As described above, the inversed F antenna 600 is configured as a three-layer ceramic substrate in the embodiment. As shown in Fig. 9, as a first layer pattern, the radiation conductor 602 and a ceramic portion 603 are sandwiched; as a second layer pattern, the feed conductor 610 and a ceramic portion 605 are sandwiched; and as a third layer pattern, the ground conductor 604 is formed. In addition, as means for short-circuiting the radiation conductor 602, the feed conductor 610, and the ground

conductor 604, the short circuit conductor 606 is configured as three elongate through-holes 606a, 606b, and 606c formed at one end portion of the ceramic substrate 650 as shown in Fig. 9. The feed line 608 through which the ground conductor 604 is coupled to the feed conductor 610 is configured as not a semi-through-hole but a through-hole in the embodiment. The radiation conductor 602, the ground conductor 604, and the feed conductor 610 are manufactured by, for example, copper clad, as similar to the fourth embodiment.

[0057]

The inversed F antenna 600 having such a configuration exhibits the same effect as the inversed F antenna 200 shown in Figs. 2(A) and 2(B). As a modified example of the embodiment, although not shown in the drawing, the short circuit conductor (606) may be configured as a through-hole, or a semi-through-hole formed by cutting the hole into half. Further, it is obvious that the short circuit conductor (606) may be configured as not the through-hole but the copper clad, as similar to the fourth embodiment.

[0058]

Next, as an antenna adjusting method according to a sixth embodiment of the present invention, a resonance frequency adjusting method for the inversed F antenna will

be described.

[0059]

The resonance frequency of the inversed F antenna is determined on the basis of the shape of the radiation conductor (electrode). Therefore, as shown in Figs. 10(a) to 10(c), the resonance frequency can be adjusted by changing a current length by making a cut in the radiation conductor (electrode) (see Fig. 10(a)), by changing the length thereof (see Fig. 10(b)), or by making a slot (see Fig. 10(c)). However, the feed line (feed system) 108 is directly attached to the radiation electrode 102 in the conventional inversed F antenna 100 as shown in Fig. 1. Therefore, the adjustment of the frequency causes changes of the current distribution on the radiation electrode 102, thus leading to impedance mismatching with the feed line (feed system) 108. As a result, it is necessary to obtain impedance matching with the feed line (feed system) 108 again (search for the feed point position again where the impedance matching can be obtained) every time the frequency is adjusted.

[0060]

On the contrary, power is fed through the feed conductor without directly feeding from the feed line (feed system) to the radiation conductor (electrode) in the inversed F antenna according to the present invention.

Therefore, if the shape of the radiation conductor (electrode) is changed to adjust the frequency, the impedance matching with the feed line (feed system) is unlikely to lose. Therefore, sufficient impedance matching can be obtained without changing the feed point position every time the frequency is adjusted.

[0061]

In the embodiment, in order to confirm that the impedance matching with the feed line (feed system) could be maintained even if the frequency was adjusted by changing the shape of the radiation conductor (electrode), the inversed F antenna in which a cut was made in the radiation conductor (electrode) was produced, and a relation between the frequency and the return loss was measured. Specifically, as similar to the above-described fourth embodiment, an inversed F antenna was formed on a multilayer resin substrate with an outer dimension of 18mm×3mm×3mm, the relation between the frequency and the return loss was measured without changing the shape other than that of the radiation conductor (electrode), in the case where a cut was not made in the radiation conductor (electrode) as shown in Fig. 11(a), in the case where an 80% cut with respect to the width of the radiation conductor (electrode) was made as shown in Fig. 11(b), and in the case where two 80% cuts as similar to the above were

made as shown in Fig. 11(c). The result is shown in Fig. 12. It was confirmed from Fig. 12 that the resonance frequency was shifted by making a cut, the levels of return loss were about -30dB or less at respective resonance points in all the cases of Figs. 11(a), 11(b), and 11(c), and if the resonance frequency was shifted, the impedance matching could be maintained.

[0062]

Next, as a modified example of the antenna adjusting method according to the sixth embodiment, two kinds of the resonance frequency of the inversed F antenna are provided, namely, multiple resonances of the inversed F antenna are provided. In the case where the multiple resonances of the inversed F antenna are provided, for example, a perturbation element is provided to the radiation conductor (electrode) (see Fig. 13(a)), or the radiation conductor (electrode) is divided into two or more and their lengths are changed (see Fig. 13(b)), as shown in Figs. 13(a) and 13(b). However, since the feed line (feed system) 108 is directly attached to the radiation electrode 102 in the conventional inversed F antenna 100 as shown in Fig. 1, multiple resonances cause changes of the current distribution on the radiation electrode 102, thus leading to impedance mismatching with the feed line (feed system) 108. As a result, it is necessary to obtain impedance

matching with the feed line (feed system) 108 again (search for the feed point position again where the impedance matching can be obtained).

[0063]

On the contrary, power is fed through the feed conductor without directly feeding from the feed line (feed system) to the radiation conductor (electrode) in the inversed F antenna according to the present invention. Therefore, if the shape of the radiation conductor (electrode) is changed to provide multiple resonances, the impedance matching with the feed line (feed system) is unlikely to lose. Therefore, sufficient impedance matching can be obtained without changing the feed point position even if the multiple resonances are provided.

[0064]

Further, as another modified example of the antenna adjusting method according to the sixth embodiment, there will be described a case in which the inversed F antenna is downsized. In this case, for example, the inversed F antenna is downsized while maintaining the resonance frequency constant by bending a tip end of the radiation conductor (electrode) to add capacity (tip-end condenser loading) as shown in Fig. 13(c). However, since the feed line (feed system) 108 is directly attached to the radiation electrode 102 in the conventional inversed F

antenna 100 as shown in Fig. 1, the downsizing causes changes of the current distribution on the radiation electrode 102, thus leading to the impedance mismatching with the feed line (feed system) 108. As a result, it is necessary to obtain impedance matching with the feed line (feed system) 108 again (search for the feed point position again where the impedance matching can be obtained).

[0065]

On the contrary, power is fed through the feed conductor without directly feeding from the feed line (feed system) to the radiation conductor (electrode) in the inversed F antenna according to the present invention. Therefore, if the shape of the radiation conductor (electrode) is changed for downsizing, the impedance matching with the feed line (feed system) is unlikely to lose. Therefore, sufficient impedance matching can be obtained without changing the feed point position even if the inversed F antenna is downsized.

[0066]

The specific embodiments of the present invention have been described above. However, the present invention is not limited thereto, but can be applied to other embodiments within a scope described in claims. For example, in the above-described first embodiment, there has been explained an example in which the feed point 213 is

located at the edge 210b of the feed conductor 210. The present invention is not limited to the case in which the feed point 213 is located at the edge 210b (or the edge 210a) of the feed conductor 210. The feed point may be located on the middle side (inner side) relative to the edge portion in the width direction of the feed conductor, and can be located at the center portion in the width direction of the feed conductor.

[0067]

Furthermore, the height of the feed conductor (the height from the ground conductor 204), in other words, a space between the feed conductor and the radiation conductor may be changed. Even in this case, the same effect as the inversed F antenna 200 shown in Figs. 2(A) and 2(B) can be basically obtained.

[0068]

In the above-described first embodiment, the length of the feed conductor 210 is formed to be substantially half (the area ratio is 1/2) that of the radiation conductor 202 as shown in Fig. 3(B), but the length of the feed conductor may be changed. Even in this case, the same effect as the inversed F antenna 200 shown in Figs. 2(A) and 2(B) can be basically obtained.

[0069]

In this case, the length (in the y-axis direction) of

the radiation conductor 202 affects the downsizing of the antenna in terms of the resonance frequency of the antenna as an electricity length from the open end to the short circuit portion (to the short circuit (short) plate 206) towards the ground conductor. However, if observing using an electromagnetic simulator, the standing waves do not rise much in the feed conductor 210, and thus it is conceivable that the feed conductor 210 is not related to the radiation of electric waves. From this point, too, the length of the feed conductor can be changed.

[0070]

[Effect of the Invention]

According to the present invention, in the inversed F antenna using, for example, the 50Ω feed line, the position of the feed pin where the impedance matching can be obtained is shifted to the position apart from the short circuit (short) pin as described above. Therefore, the range of the feed position where the impedance matching can be obtained can be widened.

[0071]

Further, the characteristic impedance of the feed line can be easily matched to the input impedance of the antenna in a broad band, and thus the frequency band of the antenna viewed from the feed point is broadened. Further, since the range of the feed position where the impedance

matching can be obtained can be widened, fluctuation in frequency with respect to change in electrical environments around the antenna is reduced. Accordingly, it is possible to provide a stable inversed F antenna with less variation of characteristics even in the case of being used in various devices.

[0072]

Furthermore, even if the shape of the radiation conductor is changed for the frequency adjustment, multiple resonances, and downsizing, it is not necessary to obtain impedance matching with the feed line (feed line) again. Therefore, even after the mounted state is determined, it is possible to easily perform the antenna adjustment, such as shifting of the frequency band by changing the shape of the radiation conductor.

[0073]

[Brief Description of the Drawings]

Fig. 1 is a perspective view showing a basic configuration of a conventional inversed F antenna;

Fig. 2(A) is a perspective view showing a basic configuration of an inverted F antenna according to a first embodiment of the present invention, and Fig. 2(B) is a side view thereof;

Fig. 3(A) is a plan view of a radiation electrode of the conventional inversed F antenna, and Fig. 3(B) is a

plan view of a feed conductor of the inversed F antenna according to the first embodiment of the present invention;

Fig. 4 is a view showing a smith chart in which feed points are offset by ±0.5mm after impedance matching is obtained in the conventional inversed F antenna;

Fig. 5 is a view showing a smith chart in which the feed points are offset by ±0.5mm after the impedance matching is obtained in the inversed F antenna according to the first embodiment of the present invention;

Fig. 6(A) is a perspective view showing a basic configuration of an inversed F antenna according to a second embodiment of the present invention, and Fig. 6(B) is a side view thereof;

Fig. 7 is a perspective view showing a basic configuration of an inversed F antenna according to a third embodiment of the present invention;

Fig. 8 is a perspective view showing a basic configuration of an inversed F antenna according to a fourth embodiment of the present invention;

Fig. 9 is a perspective view showing a basic configuration of an inversed F antenna according to a fifth embodiment of the present invention;

Figs. 10(a) to 10(c) are views, each showing a general resonance frequency adjusting method in an inversed F antenna, in which Fig. 10(a) shows a case of making a cut

in the radiation conductor (electrode), Fig. 10(b) shows a case of changing the length thereof, and Fig. 10(c) shows a case of making a slot;

Figs. 11(a) to 11(c) are views, each explaining a resonance frequency adjusting method in an inversed F antenna according to a sixth embodiment of the present invention in which Fig. 11(a) shows a case where a cut is not made in the radiation conductor (electrode), Fig. 11(b) shows a case where an 80% cut with respect to the width of the radiation conductor (electrode) is made, and Fig. 11(c) shows a case where two 80% cuts with respect to the width of the radiation conductor (electrode) are made;

Fig. 12 is a view showing a result of measuring a relation between a frequency and return loss in the cases where the cut is not made in the radiation conductor (electrode), the 80% cut with respect to the width of the radiation conductor (electrode) is made, and the two 80% cuts with respect to the width of the radiation conductor (electrode) are made as shown in Figs. 11(a) to 11(c); and

Figs. 13(a) to 13(c) are views, each explaining an inversed F antenna adjusting method, as an modified example, according to the sixth embodiment of the present invention in which Fig. 13(a) shows a case where a perturbation element is provided to the radiation conductor (electrode) for multiple resonances, Fig. 13(b) shows a case where the

radiation conductor (electrode) is divided into two or more and their lengths are changed for multiple resonances, and Fig. 13(c) shows a case where the inversed F antenna is downsized by bending a tip end of the radiation conductor (electrode) to add capacity (tip-end condenser loading).

[Description of the Reference Numeral]

100 inversed F antenna

102 radiation electrode (radiation conductor)

104 ground plate (ground conductor)

106 short circuit (short) plate

108 feed line

108a outer conductor

108b core (feed pin)

200 inversed F antenna

202 radiation conductor

204 ground conductor

206 short circuit (short) plate

208 feed line (feed pin)

210 feed conductor

208a outer conductor

208b core (feed pin)

102a edge

102b edge

111 feed point

202a edge

202b edge

210a edge

210b edge

213 feed point

300 inversed F antenna

310 feed conductor

330 spacer

400 inversed F antenna

402 radiation conductor

404 ground conductor

406 short circuit conductor

408 feed line

410 feed conductor

408a outer conductor

408b core

408L feed line

440 phenol resin substrate

445 surface

447 back surface

500 inversed F antenna

502 radiation conductor

504 ground conductor

503, 505 resin portion

506 short circuit conductor

508 feed line

510 feed conductor

550 resin substrate

600 inversed F antenna

602 radiation conductor

604 ground conductor

603, 605 ceramic portion

606 short circuit conductor

608 feed line

610 feed conductor

650 ceramic substrate

606a, 606b, 606c elongate through-hole

Fig. 10

(a)

切り込み：CUT

(b)

放射電極の長さ

アンテナの周波調整器：

LENGTH OF RADIATION ELECTRODE

FREQUENCY ADJUSTMENT OF ANTENNA

(c)

スロット：SLOT

Fig. 11

(a)

切り込み無：NO CUT

(b)

切り込み１本

放射電極周波調整器：

ONE CUT

FREQUENCY ADJUSTMENT OF RADIATION ELECTRODE

(c)

切り込み２本：TWO CUTS

Fig. 12

切込によるアンテナのリターンロス変化：CHANGE OF RETURN LOSS IN ANTENNA CAUSED BY MAKING A CUT

リターンロス：RETURN LOSS

周波数：FREQUENCY

切り込み１本：ONE CUT

切り込み２本：TWO CUTS

切り込み無：NO CUT

Fig. 13

(a)

振動素子：PERTURBATION ELEMENT

(b)

アンテナの多共振化・小型化：MULTIPLE RESONANCES AND DOWNSIZING OF ANTENNA

(c)

容量負荷：CAPACITY LOADING

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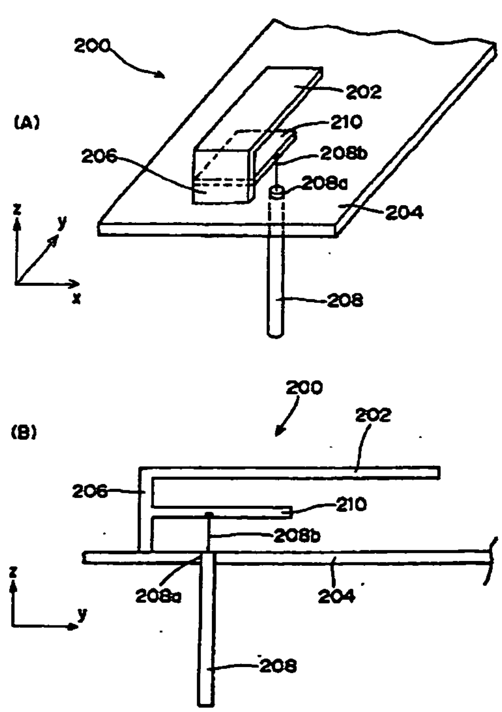
(54)【発明の名称】　逆Fアンテナ及びその給電方法並びにそのアンテナ調整方法

(57)【要約】　（修正有）
【課題】　広い範囲の周波数帯域において、給電線路の特性インピーダンスとアンテナの入力インピーダンスとの整合を取ることができる逆Fアンテナ及びその給電方法を提供すること。
【解決手段】　放射用導体２０２と、放射用導体２０２と間隔を隔てて対向して配置されたグラウンド導体２０４と、放射用導体２０２とグラウンド導体２０４とを接続する短絡手段としての短絡（ショート）板２０６と、放射用導体２０２とグラウンド導体２０４との間隔内に延設され、給電線路（給電ピン）２０８が接続された給電用導体２１０とを備えており、給電線路（給電ピン）２０８から給電用導体２１０を介して放射用導体２０２に給電する。



【特許請求の範囲】

【請求項１】　導体から成るアンテナエレメントと、該アンテナエレメントと間隔を隔てて対向して配置されたグラウンド導体と、前記アンテナエレメントと前記グラウンド導体とを接続する短絡手段と、前記アンテナエレメントに給電する給電線路とを含む逆Ｆアンテナであって、

前記アンテナエレメントを給電用導体と放射用導体とが別個に設けられた２重構造とし、前記給電線路から放射用導体に直接給電することなく、前記給電線路から前記給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナ。

【請求項２】　放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナであって、

更に、前記放射用導体と前記グラウンド導体との間隔内に延設され、前記給電線路が接続された給電用導体を備え、該給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナ。

【請求項３】　前記給電用導体は、前記短絡手段に接続され該短絡手段から前記放射用導体と前記グラウンド導体との間隔内に延設されていることを特徴とする請求項２に記載の逆Ｆアンテナ。

【請求項４】　前記給電用導体は、前記短絡手段とは離間され前記放射用導体と前記グラウンド導体との間隔内に延設されていることを特徴とする請求項２に記載の逆Ｆアンテナ。

【請求項５】　前記放射用導体が板状に形成され、前記給電用導体は、該放射用導体と所定の間隔をおいて重なり合う面積を有する板状に形成されていることを特徴とする請求項１乃至４に記載の逆Ｆアンテナ。

【請求項６】　少なくとも前記放射用導体、前記グラウンド導体、前記給電用導体が樹脂基板上の導体パターンとして形成されていることを特徴とする請求項１乃至５に記載の逆Ｆアンテナ。

【請求項７】　前記逆Ｆアンテナを少なくとも３層の樹脂基板で構成し、第１の層パターンとしての前記放射用導体と、該放射用導体と第１の樹脂部を挟んで対向する第２の層パターンとしての前記給電用導体と、該給電用導体と第２の樹脂部を挟んで対向する第３の層パターンとしての前記グラウンド導体とを含み、前記グラウンド導体と前記給電用導体とを接続する給電線路がスルーホールにより構成されていることを特徴とする請求項６に記載の逆Ｆアンテナ。

【請求項８】　前記放射用導体と前記グラウンド導体とを短絡する短絡手段が、前記樹脂基板の側面部に形成された短絡導体により形成されることを特徴とする請求項７に記載の逆Ｆアンテナ。

【請求項９】　前記放射用導体と前記グラウンド導体とを短絡する短絡手段が、スルーホールから構成されることを特徴とする請求項７に記載の逆Ｆアンテナ。

【請求項１０】　少なくとも前記放射用導体、前記グラウンド導体、前記給電用導体がセラミック基板上の導体パターンとして形成されていることを特徴とする請求項１乃至５に記載の逆Ｆアンテナ。

【請求項１１】　前記逆Ｆアンテナを少なくとも３層のセラミック基板で構成し、第１の層パターンとしての前記放射用導体と、該放射用導体と第１のセラミック部を挟んで対向する第２の層パターンとしての前記給電用導体と、該給電用導体と第２のセラミック部を挟んで対向する第３の層パターンとしての前記グラウンド導体とを含み、前記グラウンド導体と前記給電用導体とを接続する給電線路がスルーホールにより構成されていることを特徴とする請求項１０に記載の逆Ｆアンテナ。

【請求項１２】　前記放射用導体と前記グラウンド導体とを短絡する短絡手段が、前記セラミック基板の側面部に形成された短絡導体により形成されることを特徴とする請求項１１に記載の逆Ｆアンテナ。

【請求項１３】　前記放射用導体と前記グラウンド導体とを短絡する短絡手段が、スルーホールから構成されることを特徴とする請求項１１に記載の逆Ｆアンテナ。

【請求項１４】　放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナにおける給電方法であって、

更に、前記放射用導体と前記グラウンド導体との間隔内に給電用導体を延設し、該給電用導体に前記給電線路を接続することにより、前記給電線路から該給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナにおける給電方法。

【請求項１５】　放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナの調整方法であって、

前記放射用導体と前記グラウンド導体との間隔内に給電用導体を延設し、該給電用導体を介して前記放射用導体に給電するために該給電用導体に前記給電線路を接続すると共に、前記放射用導体の形状を変えることによりアンテナ調整を行うことを特徴とする逆Ｆアンテナにおけるアンテナ調整方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、逆Ｆアンテナ及びその給電方法、並びにその共振周波数の調整等のアンテナ調整方法に関し、特に、携帯通信機器、情報機器、家庭電化機器等に組み込まれる逆Ｆアンテナにおいて、ア

ンテナと給電線路のインピーダンスを整合させるための技術に関する。

【０００２】

【従来の技術】従来より、例えば、携帯電話の内臓アンテナ等、携帯通信機器等に組み込まれる小型アンテナとして、逆Ｆアンテナが知られている。この逆Ｆアンテナは、λ／４モノポールアンテナの先端を折り曲げたＬ型アンテナを低姿勢化し、給電点位置付近に短絡部を設けて給電点でのインピーダンス整合を取り易くしたものである。この線状逆Ｆアンテナを更に低姿勢化し、帯域幅を拡げ、またインピーダンス整合を取り易くするためには、折り曲げた地板に対する水平部分を板状にすればよく、この形状のアンテナを板状逆Ｆアンテナと呼んでいる。

【０００３】従来の逆Ｆアンテナの一例を図１に示す。図１は、一般に広く用いられている板状逆Ｆアンテナの基本構成を示すものである。即ち、この逆Ｆアンテナ１００は、図１に示すように、板金等の導電性金属で形成された矩形状の放射用電極（放射用導体）１０２と、この放射用電極１０２と間隔を隔てて対向して配置されたグラウンド板（グラウンド導体）１０４と、放射用電極１０２の一端側とグラウンド板１０４とを接続する短絡手段としての短絡（ショート）板１０６と、放射用電極１０２に給電する給電線路１０８とを有している。放射用電極１０２への給電は、例えば、グラウンド板１０４の背面より給電線路１０８を構成する同軸ケーブルで行い、該同軸ケーブルの外導体１０８ａはグラウンド板１０４に接続され、同軸ケーブルの芯線（又は給電ピン）１０８ｂは、該同軸ケーブルの特性インピーダンスと逆Ｆアンテナ１００の入力インピーダンスとの整合が取れるように、矩形状の放射用電極１０２の適切な位置に接続される。即ち、この従来の逆Ｆアンテナ１００では、同図に示すように、放射用電極１０２に給電線路１０８を構成する同軸ケーブルの芯線（又は給電ピン）１０８ｂを直付けして給電を行っていた。

【０００４】

【発明が解決しようとする課題】近年、携帯電話等の移動体通信が脚光を浴びており、これに伴って携帯端末機等の一層の小型化が求められている。また、このような携帯端末機等の普及に伴って、通信容量の拡大のため通信周波数帯域を拡大する必要性等により、より広帯域な特性を有するアンテナが必要とされている。一方で、アンテナは、一般に小型化すればするほど給電線路とのインピーダンス整合を得るのが困難になるという問題がある。

【０００５】上述したように、逆Ｆアンテナは、携帯電話等の内臓アンテナとして用いられることが多く、小型化が特に求められるアンテナと言える。携帯電話等にも製造メーカーにより各種の仕様のものがあり、逆Ｆアンテナが内臓される周囲の環境もそれぞれで異なる場合が多い。また、逆Ｆアンテナは、携帯電話等以外にも、各種の情報機器・家庭電化機器等に実装されて用いられる。

【０００６】このように、色々な機器に実装されて用いられるため、逆Ｆアンテナは、その入力インピーダンスが給電線路の特性インピーダンスと整合する周波数帯域が狭いと、実装状態が異なった場合には、そのアンテナ特性が変わってしまい使用に耐えなくなるという問題がある。

【０００７】例えば、図１に示した従来の逆Ｆアンテナ１００と同様の構成をセラミック・樹脂等の基板上に形成した場合（図示せず）、基板上で給電線路（給電ピン）１０８と短絡（ショート）板１０６とがより近づくこととなるため、給電線路（給電ピン）１０８のインダクタンスにより、給電線路の特性インピーダンスとアンテナの入力インピーダンスとの整合が取りにくくなり、また、かかるインピーダンス整合が取れる周波数帯域も狭くなるという問題があった。そのため、従来の逆Ｆアンテナ１００と同様の構成をある標準状態で調整してセラミック・樹脂等の基板に形成し、通信機器等において実装状態で使用した場合、基板の厚さ、搭載位置等のアンテナ周辺の電気的特性が異なると、上述したようにインピーダンスの整合帯域が狭いため、アンテナと給電系との整合度が悪化する結果、アンテナとしての感度が著しく低下するという問題がある。

【０００８】即ち、図１に示した従来の逆Ｆアンテナ１００に関し、例えば、５０Ω系の給電線路（特性インピーダンスが５０Ωの給電線路）を用いて給電を行う場合、インピーダンス整合が取れる給電位置［給電線路（給電ピン）１０８の放射用電極１０２への接続位置］は短絡（ショート）板１０６に近い位置に限られることとなり、換言すれば、インピーダンス整合が取りにくくなる。特に、逆Ｆアンテナを更に小型化するとこの傾向は強くなる。

【０００９】従来、例えば、特開平９－９８０１５号公報に記載されているように、パッチアンテナに関し、小型化に伴い給電ピンがショートピンに近づく結果、整合が取りにくくなるという同様の問題点を認識し、その解決のための構成（但し、逆Ｆアンテナの構成ではない）を開示した例はある。また、しかしながら、従来の逆Ｆアンテナにおいて、かかる問題点を解決するために特に有効な解決策は未だ提案されていないのが実情である。従って、従来の逆Ｆアンテナを更に小型化・低姿勢化したような場合でも、従前の大きめの逆Ｆアンテナと同様に、広い帯域幅においてインピーダンス整合が得られる新規な構成の逆Ｆアンテナが強く望まれる。

【００１０】一方、アンテナは電波を空間に向け放射する、空間を介して飛来する電波を受信するという性質上、アンテナ自体と共にアンテナ近傍の空間もその特性に影響を与える。従って、逆Ｆアンテナを携帯電話等の

機器に内臓した際も、近傍に物体があるとその物体にも電流が流れ、アンテナ単体の場合と異なる特性となることが多い。そのためかかる機器に内臓する逆Ｆアンテナを設計するには、逆Ｆアンテナとその逆Ｆアンテナに近接する物体を一つのアンテナ系と捉えて設計を行わなければならない。

【００１１】しかしながら、携帯電話等の機器を開発する場合、逆Ｆアンテナ等を覆うカバー等が出来上がるのは通常、開発の後期段階であるため、この後期段階で最終的な使用状態が確定してから逆Ｆアンテナの設計を開始するのでは、機器全体の開発・設計期間等との関係から間に合わないこともあり、時間の関係上難しい。そのため、携帯電話等の機器に内蔵するアンテナには、上述したように、（１）アンテナ自体が周囲の環境に影響されにくく、様々な実装状態におけるアンテナ周辺の電気的特性に対応可能なものであること、に加え、（２）実装状態が決まった後でも、周波数帯域のシフト等のアンテナ調整を簡易に行えること、が求められる。

【００１２】そこで、本発明の目的は、広い範囲の周波数帯域において、給電線路の特性インピーダンスとアンテナの入力インピーダンスとの整合を取ることができ、様々な実装状態におけるアンテナ周辺の電気的特性に対応し得る逆Ｆアンテナ及びその給電方法を提供することにある。

【００１３】また、本発明の他の目的は、更に、周波数帯域のシフト等のアンテナ調整を簡易に行うことができる逆Ｆアンテナ及びその調整方法を提供することにある。

【００１４】

【課題を解決するための手段】上記目的を達成するため、本発明に係る逆Ｆアンテナは、給電線路から放射用導体に直接給電するのではなく、グラウンド導体と間隔をおいて配置され一端側が開放端を構成するアンテナエレメントとしての導体（電極）を給電用導体（電極）と放射用導体（電極）とを別個とした２重構造とし、この給電用導体（電極）を介して放射用導体（電極）に給電するようにした。

【００１５】これにより、逆Ｆアンテナを従来よりも更に小型化・低姿勢化したような場合でも、従前の大きめの逆Ｆアンテナと同様に、広い帯域幅においてアンテナと給電線路のインピーダンス整合を取れるようになった。従って、様々な実装状態におけるアンテナ周辺の電気的特性に対応し得る逆Ｆアンテナ及びその給電方法が得られる。

【００１６】また、上記の２重構造における放射用導体の形状を変えることにより、共振周波数調整、多共振化、小型化等のアンテナ調整を行うようにした。

【００１７】これにより、アンテナと給電線路のインピーダンス整合を崩すことなく、かかるアンテナ調整を行うことができる。

【００１８】しかして、本発明の一様相によれば、導体から成るアンテナエレメントと、該アンテナエレメントと間隔を隔てて対向して配置されたグラウンド導体と、前記アンテナエレメントと前記グラウンド導体とを接続する短絡手段と、前記アンテナエレメントに給電する給電線路とを含む逆Ｆアンテナであって、前記アンテナエレメントを給電用導体と放射用導体とが別個に設けられた２重構造とし、前記給電線路から放射用導体に直接給電することなく、前記給電線路から前記給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナが得られる。

【００１９】ここでいう「グラウンド導体」は、アンテナ自体のグラウンドでなくともよい。即ち、逆Ｆアンテナ自体はグラウンドを有していない場合で、携帯端末機等において送受信回路等が配置されるＲＦ回路実装用基板、端末操作用キー等に接続されるベースバンド回路実装用基板等のアンテナが実装される基板がグラウンドになる場合の当該グラウンド基板も含む趣旨である。

【００２０】ここに「給電用導体」は、「給電線路」とは独立した構成要素であり、「給電線路」を構成する導体部、例えば、同軸ケーブルの内部導体等は含まない趣旨である。但し、後述する樹脂・セラミック等の基板上に導体パターンにより「給電線路」と「給電用導体」とを一体的に形成する場合を含んで良い。また、「給電用導体」は、「放射用導体」と平行であるのが好適であるが、平行でなくても良い。但し、平行であれば、製作し易いという利点もある。また、「給電用導体」は、板状であるのが好適であるが、板状ではなく、線状（棒状）でも良い。

【００２１】また、本発明の他の様相によれば、放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナであって、更に、前記放射用導体と前記グラウンド導体との間隔内に延設され、前記給電線路が接続された給電用導体を備え、該給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナが得られる。

【００２２】ここに、前記給電用導体は、前記短絡手段に接続され該短絡手段から前記放射用導体と前記グラウンド導体との間隔内に延設されていても良い。一方、前記給電用導体は、前記短絡手段とは離間され前記放射用導体と前記グラウンド導体との間隔内に延設されていても良い。

【００２３】また、前記放射用導体が板状に形成され、前記給電用導体は、該放射用導体と所定の間隔をおいて重なり合う面積を有する板状に形成されているのが望ましい。

【００２４】更に、少なくとも前記放射用導体、前記グラウンド導体、前記給電用導体を樹脂又はセラミック基

板上の導体パターンとして形成しても良い。

【００２５】尚、前記逆Ｆアンテナを少なくとも３層の樹脂又はセラミック基板で構成し、第１の層パターンとしての前記放射用導体と、該放射用導体と第１の樹脂又はセラミック部を挟んで対向する第２の層パターンとしての前記給電用導体と、該給電用導体と第２の樹脂又はセラミック部を挟んで対向する第３の層パターンとしての前記グラウンド導体とを含み、前記グラウンド導体と前記給電用導体とを接続する給電線路をスルーホールにより構成することができる。

【００２６】ここで、前記放射用導体と前記グラウンド導体とを短絡する短絡手段は、前記樹脂又はセラミック基板の側面部に形成された短絡導体により形成しても良い。或いは、前記放射用導体と前記グラウンド導体とを短絡する短絡手段は、スルーホールにより構成しても良い。

【００２７】尚、「給電線路」を「給電用導体」に接続する位置（給電位置）は、製造の容易性等を考慮すれば、「給電用導体」の幅方向端部（エッジ部）が好適であるが、「給電用導体」の幅方向中央部でも良い。

【００２８】そして、本発明の別個の様相によれば、放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナにおける給電方法であって、更に、前記放射用導体と前記グラウンド導体との間隔内に給電用導体を延設し、該給電用導体に前記給電線路を接続することにより、前記給電線路から該給電用導体を介して前記放射用導体に給電することを特徴とする逆Ｆアンテナにおける給電方法が得られる。

【００２９】また、本発明の更に別個の様相によれば、放射用導体と、該放射用導体と間隔を隔てて対向して配置されたグラウンド導体と、前記放射用導体と前記グラウンド導体とを接続する短絡手段と、前記放射用導体に給電する給電線路とを含む逆Ｆアンテナの調整方法であって、前記放射用導体と前記グラウンド導体との間隔内に給電用導体を延設し、該給電用導体を介して前記放射用導体に給電するために該給電用導体に前記給電線路を接続すると共に、前記放射用導体の形状を変えることによりアンテナ調整を行うことを特徴とする逆Ｆアンテナにおけるアンテナ調整方法が得られる。

【００３０】ここに、「放射用導体の形状を変える」とは、例えば、共振周波数を調整するために、放射用導体に切り込みを入れる、その長さを変える、スロットを入れる等、また、多共振化を行うために、放射用導体に摂動素子を設ける、放射用導体を２以上に分けそれぞれの長さを変える等、更に、小型化のために、放射用導体の先端を折り曲げ容量を付加（先端コンデンサ装荷）する等、放射用導体の形状を変化させる全ての工程を含む。一方、「アンテナ調整」には、共振周波数の調整、多共振化、小型化等のためにアンテナとしての特性・形状等を調整する全ての場合を含む。

【００３１】

【発明の実施の形態】以下、本発明の実施の形態を、図面を参照しつつさらに具体的に説明する。図２（Ａ）は、本発明の第１の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図であり、図２（Ｂ）は、その側面図である。この逆Ｆアンテナ２００は、図２（Ａ）及び（Ｂ）に示すように、導体から成るアンテナエレメント（２０２、２１０）、アンテナエレメント（２０２、２１０）と間隔を隔てて対向して配置されたグラウンド導体（２０４）と、アンテナエレメント（２０２、２１０）とグラウンド導体（２０４）とを接続する短絡手段（２０６）と、アンテナエレメント（２０２、２１０）に給電する給電線路（２０８）とを含む逆Ｆアンテナであって、アンテナエレメント（２０２、２１０）を給電用導体（２１０）と放射用導体（２０２）とが別個に設けられた２重構造とし、給電線路（２０８）から放射用導体（２０２）に直接給電することなく、給電線路（２０８）から給電用導体（２１０）を介して放射用導体（２０２）に給電するという機能を有している。

【００３２】即ち、この逆Ｆアンテナ２００は、図２（Ａ）及び（Ｂ）に示すように、放射用導体２０２と、放射用導体２０２と間隔を隔てて対向して配置されたグラウンド導体２０４と、放射用導体２０２とグラウンド導体２０４とを接続する短絡手段としての短絡（ショート）板２０６と、放射用導体２０２とグラウンド導体２０４との間隔内に延設され、給電線路（給電ピン）２０８が接続された給電用導体２１０とを備えており、給電線路（給電ピン）２０８から給電用導体２１０を介して放射用導体２０２に給電する構成を有している。給電線路（給電ピン）２０８から給電用導体２１０への給電は、例えば、グラウンド導体２０４の背面より給電線路２０８を構成する同軸ケーブルで行い、該同軸ケーブルの外導体２０８ａはグラウンド導体２０４に接続され、同軸ケーブルの芯線（又は給電ピン）２０８ｂは、該同軸ケーブルの特性インピーダンスと逆Ｆアンテナ２００の入力インピーダンスとの整合が取れるように、給電用導体２１０の適切な位置に接続される。即ち、この逆Ｆアンテナ２００では、同図に示すように、放射用導体２０２ではなく、給電用導体２１０へ給電線路２０８を構成する同軸ケーブルの芯線（又は給電ピン）２０８ｂを直付けし、給電用導体２１０を介して放射用導体２０２に給電を行う。

【００３３】本実施形態では、給電用導体２１０は、図２（Ｂ）に示すように、短絡（ショート）板２０６に接続され短絡（ショート）板２０６から放射用導体２０２とグラウンド導体２０４との間隔内に延設されている。

【００３４】また、本実施形態では、放射用導体２０２は板状に形成されている。給電用導体２１０も、放射用

導体２０２と所定の間隔をおいて重なり合う面積を有する板状に形成されている。

【００３５】尚、変形例として、図示はしないが、放射用導体２０２は板状に形成し、給電用導体２１０は、棒状或いは線状に構成しても良い。また、放射用導体２０２と給電用導体２１０の双方を棒状或いは線状に構成し、更に、短絡（ショート）板２０６を短絡導体として棒状或いは線状に構成しても良い。この場合には、アンテナ構成が板状逆Ｆアンテナではなく、線状逆Ｆアンテナとなるが、この場合でも、本実施形態の板状逆Ｆアンテナの後述する作用効果は、略同様に得られる。

【００３６】図３（Ａ）は、従来の逆Ｆアンテナ１００の放射用電極１０２を上から見た図である。図３（Ｂ）は、本実施の形態の逆Ｆアンテナ２００の給電用導体２１０を上から見た図であり、その放射用導体２０２を破線にて示している。

【００３７】本実施形態では、図１、図２にそれぞれ示した従来の逆Ｆアンテナ１００と本実施の形態の逆Ｆアンテナ２００の給電系から見たインピーダンスを電磁界シミュレーターで計算し比較を行った。

【００３８】ここでは、無限地板上に同体積１５ｍｍ×３ｍｍ×３ｍｍの従来の逆Ｆアンテナ１００と本実施の形態の逆Ｆアンテナ２００を構成し、それぞれの給電点１１１、２１３を変化させ給電系から見たリターンロスを見た。両アンテナは共に導電率４．９×１０７、厚さ１８μｍの導体板で構成した。それぞれ短絡（ショート）板１０６、２０６の位置をｙ＝０とし、整合の取れる給電点位置を求め、そこから給電点位置を±０．５ｍｍずらしたときのリターンロスの変化を見た。まず、従来の逆Ｆアンテナ１００ではｙ＝１．５ｍｍ、本実施の形態の逆Ｆアンテナ２００ではｙ＝３．５ｍｍの位置に給電点を持ってきた時に、給電線路の特性インピーダンスとアンテナのインピーダンスとの整合を取ることができた。従って、本実施の形態の逆Ｆアンテナ２００では、従来の逆Ｆアンテナ１００に比べ、給電点位置が短絡（ショート）板２０６からより遠くなった。図４に従来の逆Ｆアンテナ１００、図５に本実施の形態の逆Ｆアンテナ２００において、整合が取れたとき、それから、給電点をそれぞれ±０．５ｍｍオフセットさせたときのスミスチャートを示す。なお、周波数範囲は３～５ＧＨｚまでとし、両アンテナの共振周波数は４．２５ＧＨｚとなった。

【００３９】給電線路１０８、２０８は、それぞれ上述した５０Ω系の給電線路（特性インピーダンスが５０Ωの給電線路）であり、この５０Ωが円の中心に来る。両スミスチャート上、丸、四角、菱形によりそれぞれプロットした各点は、アンテナのインピーダンスの周波数変化をプロットしたものである。従って、プロットした点（を結んで得られる円弧）がスミスチャートの中心である５０Ωからずれない方が、特性上好ましいことになる。

【００４０】従来例では、給電点位置を基準位置からそれぞれ±０．５ｍｍオフセットすると、プロットした点（を結んで得られる円弧）がスミスチャートの中心である５０Ωから大きくずれてしまうのに対し、本実施形態では、同様に０．５ｍｍずらした場合でも、スミスチャートの中心である５０Ωからそれ程ずれていない。

【００４１】両図より、本実施の形態の逆Ｆアンテナ２００では、給電位置がオフセットされた場合でもインピーダンスの変動が少ないことが分かった。本発明者は、この原因について考察するため、電磁界シミュレーターを用いて、まず、図１及び図３（Ａ）に示した従来の逆Ｆアンテナ１００について、その定在波分布を観察した。この従来の逆Ｆアンテナ１００では、図３（Ａ）に示した放射用電極１０２上のｙ軸と平行な辺の両エッジ１０２ａ、１０２ｂ付近に電流の定在波が立ち、それが放射源となる。図１及び図３（Ａ）に示した従来の逆Ｆアンテナ１００では、放射用電極１０２上のｙ軸と平行な辺の両エッジ１０２ａ、１０２ｂ付近に立つ定在波は左右非対称になっていることを確認した。これは、定在波が立つエッジ部分に給電点１１１が位置しているため、給電点１１１が位置する側のエッジ１０２ｂ付近に立つ定在波が給電系により乱されるためと考えられる。このような放射用電極１０２への直接給電による外乱も一因となって、インピーダンス整合の取れる給電位置が狭くなり、また、アンテナの放射効率が低下するものと推察される。特に、逆Ｆアンテナ１００を更に小型化した場合、放射用電極１０２等から成るアンテナエレメント自体の大きさに比べ、給電系の大きさが無視できなくなるため、この給電系とアンテナエレメントとの相互結合による影響が大きくなることが予想される。

【００４２】本発明者は、同様に電磁界シミュレーターを用いて、次に、本実施の形態の逆Ｆアンテナ２００について、その定在波分布を観察した。この本実施の形態の逆Ｆアンテナ２００では、従来の逆Ｆアンテナ１００と同様に、図２に実線で、また図３（Ｂ）に破線で示した放射用導体２０２上のｙ軸と平行な辺の両エッジ２０２ａ、２０２ｂ付近に電流の定在波が立ち、それが放射源となるが、図２及び図３（Ｂ）に示した放射用導体２０２上のｙ軸と平行な辺の両エッジ２０２ａ、２０２ｂ付近に立つ定在波は左右対称になっていることを確認した。

【００４３】これは、給電用導体２１０のエッジ２１０ｂ部分に給電点２１３が位置しているものの、放射用導体２０２に直接給電するのではなく、給電用導体２１０を介して給電しているため、放射用導体２０２上のｙ軸と平行な辺の両エッジ２０２ａ、２０２ｂ付近に立つ定在波が給電系により乱されることが比較的少なく給電できるためと推察される。そして、このように放射用導体２０２への直接給電による外乱が少ないこともインピー

ダンス整合の取れる給電位置がより広くなる一因と考えられる。

【００４４】図６（Ａ）は、本発明の第２の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図であり、図６（Ｂ）は、その側面図である。この逆Ｆアンテナ３００は、逆Ｆアンテナとしての基本構成は図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と略同一であるが、給電用導体３１０が短絡（ショート）板２０６とは接続されていない点で異なる構成となっている。即ち、給電用導体３１０は、短絡（ショート）板２０６とは離間されつつ、放射用導体２０２とグラウンド導体２０４との間隔内に延設されている。このような構成の逆Ｆアンテナ３００も、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と同様の作用効果を奏する。尚、本実施形態の逆Ｆアンテナ３００では、給電用導体３１０が短絡（ショート）板２０６とは接続されていないため、この給電用導体３１０を支持するために、例えば、図６（Ｂ）に破線で示すように、グラウンド導体２０４と給電用導体３１０との間に絶縁体から成るスペーサ３３０を挿入固定する等の必要がある。

【００４５】また、本実施形態においても、放射用導体２０２は板状に形成されている。給電用導体３１０も、放射用導体２０２と所定の間隔をおいて重なり合う面積を有する板状に形成されている。

【００４６】図７は、本発明の第３の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。この逆Ｆアンテナ４００は、逆Ｆアンテナとしての基本的な構成要素は図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と略同一であるが、アンテナを樹脂基板上に形成した点で異なる構成となっている。

【００４７】即ち、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と略同様に、この逆Ｆアンテナ４００は、図７に示すように、放射用導体４０２と、放射用導体４０２と間隔を隔てて対向して配置されたグラウンド導体４０４と、放射用導体４０２とグラウンド導体４０４とを接続する短絡手段としての短絡導体４０６と、放射用導体４０２とグラウンド導体４０４との間隔内に延設され、給電線路４０８が接続された給電用導体４１０とを備えており、給電線路４０８から給電用導体４１０を介して放射用導体４０２に給電する構成を有している。そして、これら放射用導体４０２、グラウンド導体４０４、短絡導体４０６、及び給電用導体４１０と給電線路４０８の一部を構成する給電路４０８Ｌが、一枚の、例えばフェノール樹脂基板４４０の表面４４５に形成されている。これらは、すべてフェノール樹脂基板４４０の銅張の部分であり、作製時には、例えば、これら部分だけを残すようにエッチングを行う。尚、給電線路４０８を構成する同軸ケーブルの外導体４０８ａはグラウンド導体４０４に接続され、給電線路４０８から給電用導体４１０への給電は、同軸ケーブルの芯線４０８ｂと給電路４０８Ｌとを相互接続して行う。

【００４８】このような構成の逆Ｆアンテナ４００も、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と同様の作用効果を奏する。尚、少なくとも放射用導体４０２、グラウンド導体４０４、給電用導体４１０が樹脂基板上の導体パターンとして形成されていれば良い。また、本実施形態では、上述した構成要素をフェノール樹脂基板４４０の表面４４５のみに形成したが、一部の構成要素を裏面４４７に形成するようにしても良い。

【００４９】尚、変形例として、同様の逆Ｆアンテナをセラミック基板上に形成することも考えられ、上記の樹脂基板上に形成した逆Ｆアンテナ４００と同様の作用効果を奏するものと考えられる。尚、少なくとも放射用導体、グラウンド導体、給電用導体がセラミック基板上の導体パターンとして形成されていれば良い。

【００５０】図８は、本発明の第４の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。この逆Ｆアンテナ５００は、逆アンテナを樹脂基板上に形成したのは図７の逆Ｆアンテナ４００と同様であるが、逆アンテナを多層樹脂基板上に形成した点で異なる構成となっている。

【００５１】即ち、この逆Ｆアンテナ５００は、図８に示すように、放射用導体５０２と、放射用導体５０２と間隔を隔てて対向して配置されたグラウンド導体５０４と、放射用導体５０２とグラウンド導体５０４とを接続する短絡手段としての短絡導体５０６と、放射用導体５０２とグラウンド導体５０４との間隔内に延設され、給電線路５０８が接続される給電用導体５１０とを備えており、給電線路５０８から給電用導体５１０を介して放射用導体５０２に給電する構成を有している。そして、放射用導体５０２、グラウンド導体５０４及び給電用導体５１０が、樹脂基板５５０上に３層に亘って形成されている。

【００５２】このように、本実施形態では、逆Ｆアンテナ５００を３層樹脂基板で構成する。図８に示すように、第１層パターンで放射用導体５０２、樹脂部５０３を挟んで、第２層パターンで給電用導体５１０、樹脂部５０５を挟んで、第３層パターンでグラウンド導体５０４を形成する。また、放射用導体５０２、給電用導体５１０、グラウンド導体５０４を短絡する手段としては、樹脂基板５５０の側面部に短絡導体５０６が形成されている。更に、グラウンド導体５０４と給電用導体５１０とを接続する給電線路５０８は、半スルーホールにより構成されている。樹脂基板５５０は、例えば、フェノール樹脂により作製され、放射用導体５０２、グラウンド導体５０４、短絡導体５０６、給電用導体５１０は、銅張等により作製される。

【００５３】このような構成の逆Ｆアンテナ５００も、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と同様の作用効果を奏する。尚、本実施形態の変形例として、図示

はしないが、短絡導体（５０６）を、長穴スルーホール、スルーホール、もしくは、これらを半分に切断した半スルーホールにより構成してもよい。

【００５４】図９は、本発明の第５の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。この逆Ｆアンテナ６００は、逆Ｆアンテナを多層基板上に形成したのは図８の逆Ｆアンテナ５００と同様であるが、逆Ｆアンテナを多層セラミック基板上に形成した点で異なる構成となっている。

【００５５】即ち、この逆Ｆアンテナ６００は、図９に示すように、放射用導体６０２と、放射用導体６０２と間隔を隔てて対向して配置されたグラウンド導体６０４と、放射用導体６０２とグラウンド導体６０４とを接続する短絡手段としての短絡導体６０６と、放射用導体６０２とグラウンド導体６０４との間隔内に延設され、給電線路６０８が接続される給電用導体６１０とを備えており、給電線路６０８から給電用導体６１０を介して放射用導体６０２に給電する構成を有している。そして、放射用導体６０２、グラウンド導体６０４及び給電用導体６１０が、セラミック基板６５０上に３層に亘って形成されている。

【００５６】このように、本実施形態では、逆Ｆアンテナ６００を３層セラミック基板で構成する。図９に示すように、第１層パターンで放射用導体６０２、セラミック部６０３を挟んで、第２層パターンで給電用導体６１０、セラミック部６０５を挟んで、第３層パターンでグラウンド導体６０４を形成する。また、放射用導体６０２、給電用導体６１０、グラウンド導体６０４を短絡する手段としては、短絡導体６０６を、図９に示すように、樹脂基板６５０の一端部に形成された３つの長穴スルーホール６０６ａ、６０６ｂ、６０６ｃにより構成している。尚、グラウンド導体６０４と給電用導体６１０とを接続する給電線路６０８は、本実施形態では、半スルーホールではなく、スルーホールにより構成している。放射用導体６０２、グラウンド導体６０４、給電用導体６１０は、第４の実施形態と同様に、例えば、銅張等により作製される。

【００５７】このような構成の逆Ｆアンテナ６００も、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と同様の作用効果を奏する。尚、本実施形態の変形例としても、図示はしないが、短絡導体（６０６）を、スルーホール、もしくは、これらを半分に切断した半スルーホールにより構成してもよい。また、スルーホールではなく、第４の実施形態と同様に、例えば、銅張等により構成してもよいのは勿論である。

【００５８】次に、本発明の第６の実施形態に係るアンテナ調整方法として、逆Ｆアンテナの共振周波数調整方法について述べる。

【００５９】逆Ｆアンテナの共振周波数は、放射用導体（電極）の形状により決まってくる。そのため、図１０（ａ）～（ｃ）に示すように、例えば、放射用導体（電極）に切り込みを入れる［同図（ａ）参照］、その長さを変える［同図（ｂ）参照］、スロットを入れる［同図（ｃ）参照］等を行い、電流長を変化させることで共振周波数を調整することができる。しかしながら、従来の逆Ｆアンテナ１００では、図１に示したように、放射用電極１０２に給電線路（給電系）１０８を直付けしていたため、周波数調整を行うと放射用電極１０２上の電流分布が変化することとなり、給電線路（給電系）１０８とのインピーダンス整合が取れなくなる。この結果、周波数調整を行う度に給電線路（給電系）１０８とのインピーダンス整合を取り直す（整合が取れる給電点位置を探し直す）必要があった。

【００６０】これに対し、本発明の逆Ｆアンテナでは、給電線路（給電系）から放射用導体（電極）に直接給電することなく、給電用導体を介して給電しているため、周波数調整を行うために放射用導体（電極）の形状を変えても給電線路（給電系）とのインピーダンス整合は崩れにくい。従って、周波数調整を行う度に給電点位置を変更しなくても充分なインピーダンス整合を取ることができる。

【００６１】本実施形態では、放射用導体（電極）の形状を変えて周波数調整を行っても、給電線路（給電系）とのインピーダンス整合を維持できることを確認するため、放射用導体（電極）に切り込みを入れた逆Ｆアンテナを作製し、その周波数と反射損失との関係を測定した。即ち、上述した第４の実施形態と略同様に、外形が１８ｍｍ×３ｍｍ×３ｍｍの多層樹脂基板に逆Ｆアンテナを形成し、放射用導体（電極）の形状以外は全く変えずに、図１１（ａ）に示すように、放射用導体（電極）に切り込みを入れない場合、同図（ｂ）に示すように、放射用導体（電極）の幅に対し８０％の切り込みを１本入れた場合、同様の８０％の切り込みを、同図（ｃ）に示すように、２本入れた場合のそれぞれにつき、周波数と反射損失（リターンロス）との関係を測定した。その結果を図１２に示す。図１２から、切り込みを入れることにより共振周波数がシフトすること、また、反射損失（リターンロス）の大きさは、（ａ）、（ｂ）、（ｃ）すべての場合について各共振点において、略－３０ｄＢ以下になっており、共振周波数がシフトしてもインピーダンス整合が維持されることを確認することができた。

【００６２】続いて、第６の実施形態のアンテナ調整方法の変形例として、逆Ｆアンテナの共振周波数を２つ以上にする、即ち、逆Ｆアンテナの多共振化を行う場合について述べる。逆Ｆアンテナの多共振化を行う場合には、一般的に、図１３（ａ）及び（ｂ）に示すように、例えば、放射用導体（電極）に摂動素子を設ける［同図（ａ）参照］、放射用導体（電極）を２以上に分けそれぞれの長さを変える［同図（ｂ）参照］等を行う。しかしながら、従来の逆Ｆアンテナ１００では、図１に示し

たように、放射用電極１０２に給電線路（給電系）１０８を直付けしていたため、かかる多共振化を行うと放射用電極１０２上の電流分布が変化することとなり、給電線路（給電系）１０８とのインピーダンス整合が取れなくなる。この結果、給電線路（給電系）１０８とのインピーダンス整合を取り直す（整合が取れる給電点位置を探し直す）必要があった。

【００６３】これに対し、本発明の逆Ｆアンテナでは、給電線路（給電系）から放射用導体（電極）に直接給電することなく、給電用導体を介して給電しているため、多共振化を行うために放射用導体（電極）の形状を変えても給電線路（給電系）とのインピーダンス整合は崩れにくい。従って、多共振化を行った場合でも、給電点位置を変更しなくても充分なインピーダンス整合を取ることができる。

【００６４】更に、第６の実施形態のアンテナ調整方法の他の変形例として、逆Ｆアンテナの小型化を行う場合について述べる。かかる場合、例えば、図１３（ｃ）に示すように、放射用導体（電極）の先端を折り曲げ容量を付加（先端コンデンサ装荷）することで共振周波数を同じに保ちながら逆Ｆアンテナの小型化を行う。しかしながら、従来の逆Ｆアンテナ１００では、図１に示したように、放射用電極１０２に給電線路（給電系）１０８を直付けしていたため、かかる小型化を行うと放射用電極１０２上の電流分布が変化することとなり、給電線路（給電系）１０８とのインピーダンス整合が取れなくなる。この結果、給電線路（給電系）１０８とのインピーダンス整合を取り直す（整合が取れる給電点位置を探し直す）必要があった。

【００６５】これに対し、本発明の逆Ｆアンテナでは、給電線路（給電系）から放射用導体（電極）に直接給電することなく、給電用導体を介して給電しているため、小型化を行うために放射用導体（電極）の形状を変えても給電線路（給電系）とのインピーダンス整合は崩れにくい。従って、小型化を行った場合でも、給電点位置を変更しなくても充分なインピーダンス整合を取ることができる。

【００６６】以上、本発明を特定の実施形態について述べたが、本発明はこれらに限られるものではなく、特許請求の範囲に記載した範囲内で他の実施形態についても適用される。例えば、上述した第１の実施形態では、給電用導体２１０のエッジ２１０ｂ部分に給電点２１３が位置している例について説明したが、本発明は、給電点２１３が給電用導体２１０のエッジ２１０ｂ部分（或いは、エッジ２１０ａ部分）に位置している場合に限られない。給電点は給電用導体の幅方向エッジ部より中側（内側）に位置しても良く、給電用導体の幅方向中央部に位置させることも可能である。

【００６７】更に、給電用導体の高さ（グラウンド導体２０４からの高さ）、換言すれば、給電用導体の放射用導体との間隔を変えても良い。この場合にも、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と基本的に同様の作用効果が得られる。

【００６８】尚、上述した第１の実施形態では、給電用導体２１０は、図３（Ｂ）に示したように、放射用導体２０２の長さの略半分の長さ（面積比が１／２）に形成されているが、給電用導体の長さを変えても良い。この場合にも、図２（Ａ）及び（Ｂ）の逆Ｆアンテナ２００と基本的に同様の作用効果が得られる。

【００６９】この場合、放射用導体２０２の（ｙ軸方向の）長さは、開放端からグラウンド導体への短絡部まで［短絡（ショート）板２０６まで］の電気長として、アンテナの共振周波数との関係でアンテナの小型化にも関係するが、電磁界シミュレーターを用いて観察しても、給電用導体２１０には、あまり定在波は立っていないので、給電用導体２１０は、電波の放射等には関与していないものと推察される。この点からも、給電用導体の長さを変えることは可能である。

【００７０】

【発明の効果】以上説明したように、本発明によれば、例えば、５０Ω系の給電線路を用いた逆Ｆアンテナにおいて、インピーダンス整合の取れる給電ピンの位置が短絡（ショート）ピンから離れた位置に移る。従って、インピーダンス整合の取れる給電位置の範囲が広くなる。

【００７１】また、給電線路の特性インピーダンスとアンテナの入力インピーダンスとの整合が広い帯域において取り易いので、給電点からアンテナを見たときの周波数帯域が広くなる。更に、インピーダンス整合の取れる給電位置の範囲が広くなるから、アンテナ周囲の電気的環境の変化に対する周波数変動が少なくなる。よって、各種機器に使用しても特性のバラツキが少ない安定した逆Ｆアンテナを提供することができる。

【００７２】更に、放射用導体の形状を変えることにより周波数調整、多共振化、小型化を行っても、給電線路（給電系）とのインピーダンス整合を取り直す必要が無い。従って、実装状態が決まった後でも、放射用導体の形状を変えて周波数帯域のシフト等のアンテナ調整を簡易に行うことが可能である。

【００７３】

【図面の簡単な説明】

【図１】従来の逆Ｆアンテナの基本構成を示す斜視図である。

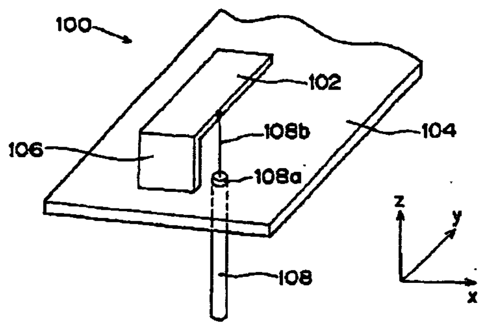
【図２】（Ａ）は、本発明の第１の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図であり、（Ｂ）は、その側面図である。

【図３】（Ａ）は、従来の逆Ｆアンテナの放射用電極の平面図、（Ｂ）は、本発明の第１の実施形態に係る逆Ｆアンテナの給電用導体の平面図である。

【図４】従来の逆Ｆアンテナにおいて、整合が取れたとき、給電点をそれぞれ±０．５mmオフセットさせたと

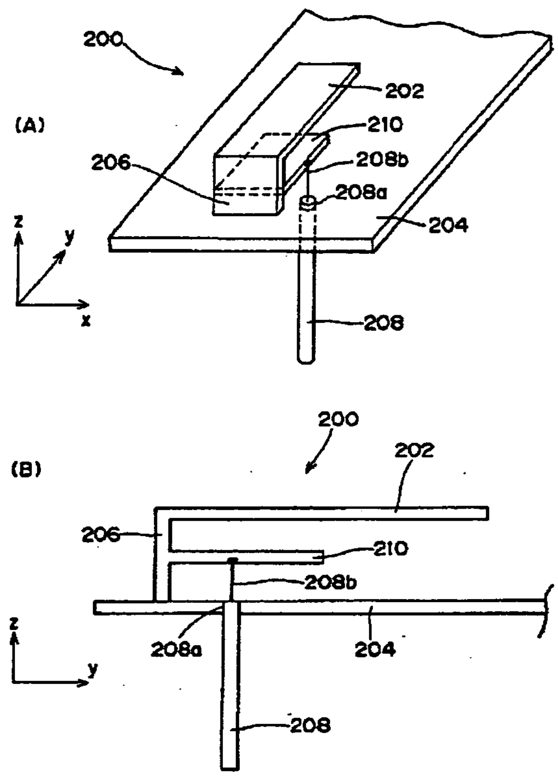
きのスミスチャートを示す図である。
【図５】本発明の第１の実施形態に係る逆Ｆアンテナにおいて、整合が取れたとき、給電点をそれぞれ±０．５ｍｍオフセットさせたときのスミスチャートを示す図である。
【図６】（Ａ）は、本発明の第２の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図であり、（Ｂ）は、その側面図である。
【図７】本発明の第３の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。
【図８】本発明の第４の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。
【図９】本発明の第５の実施形態に係る逆Ｆアンテナの基本構成を示す斜視図である。
【図１０】逆Ｆアンテナにおける一般的な共振周波数調整方法を示す図であり、（ａ）は放射用導体（電極）に切り込みを入れる場合、（ｂ）はその長さを変える場合、（ｃ）はスロットを入れる場合をそれぞれ示す。
【図１１】本発明の第６の実施形態に係る、逆Ｆアンテナの共振周波数調整方法について説明するための図であり、（ａ）は放射用導体（電極）に切り込みを入れない場合、（ｂ）は放射用導体（電極）の幅に対し８０％の切り込みを１本入れた場合、（ｃ）は放射用導体（電極）の幅に対し８０％の切り込みを２本入れた場合をそれぞれ示す。
【図１２】図１１（ａ）～（ｃ）に示した、放射用導体（電極）に切り込みを入れない場合、放射用導体（電極）の幅に対し８０％の切り込みを１本入れた場合、同様の８０％の切り込みを２本入れた場合のそれぞれにつき、周波数と反射損失（リターンロス）との関係を測定した結果を示す図である。
【図１３】本発明の第６の実施形態の変形例としての逆Ｆアンテナの調整方法について説明するための図であり、（ａ）は放射用導体（電極）に摂動素子を設けて多共振化を行う場合、（ｂ）は放射用導体（電極）を２以上に分けそれぞれの長さを変えることで多共振化を行う場合、（ｃ）は放射用導体（電極）の先端を折り曲げ容量を付加（先端コンデンサ装荷）することで逆Ｆアンテナの小型化を行う場合をそれぞれ示す。
【符号の説明】
１００　逆Ｆアンテナ
１０２　放射用電極（放射用導体）
１０４　グラウンド板（グラウンド導体）
１０６　短絡（ショート）板
１０８　給電線路
１０８ａ　外導体
１０８ｂ　芯線（給電ピン）
２００　逆Ｆアンテナ
２０２　放射用導体
２０４　グラウンド導体
２０６　短絡（ショート）板
２０８　給電線路（給電ピン）
２１０　給電用導体
２０８ａ　外導体
２０８ｂ　芯線（給電ピン）
１０２ａ　エッジ
１０２ｂ　エッジ
１１１　給電点
２０２ａ　エッジ
２０２ｂ　エッジ
２１０ａ　エッジ
２１０ｂ　エッジ
２１３　給電点
３００　逆Ｆアンテナ
３１０　給電用導体
３３０　スペーサ
４００　逆Ｆアンテナ
４０２　放射用導体
４０４　グラウンド導体
４０６　短絡導体
４０８　給電線路
４１０　給電用導体
４０８ａ　外導体
４０８ｂ　芯線
４０８Ｌ　給電路
４４０　フェノール樹脂基板
４４５　表面
４４７　裏面
５００　逆Ｆアンテナ
５０２　放射用導体
５０４　グラウンド導体
５０３、５０５　樹脂部
５０６　短絡導体
５０８　給電線路
５１０　給電用導体
５５０　樹脂基板
６００　逆Ｆアンテナ
６０２　放射用導体
６０４　グラウンド導体
６０３、６０５　セラミック部
６０６　短絡導体
６０８　給電線路
６１０　給電用導体
６５０　セラミック基板
６０６ａ、６０６ｂ、６０６ｃ　長穴スルーホール

【図１】



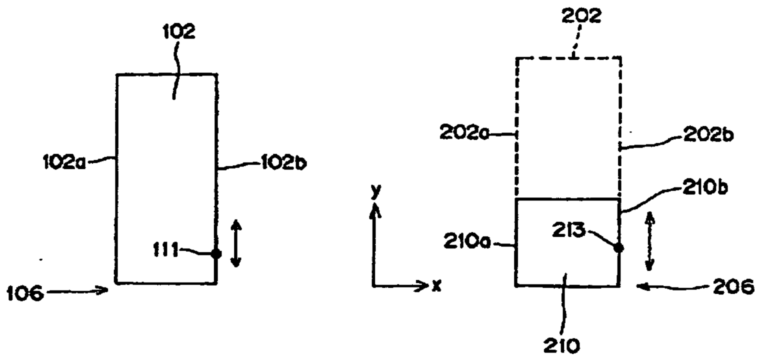
【図２】

(A)



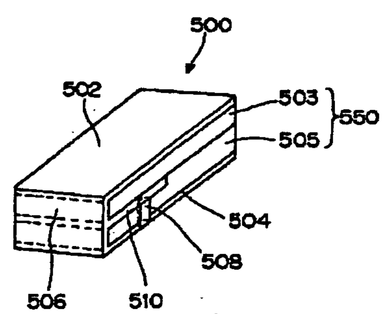
(B)

【図３】

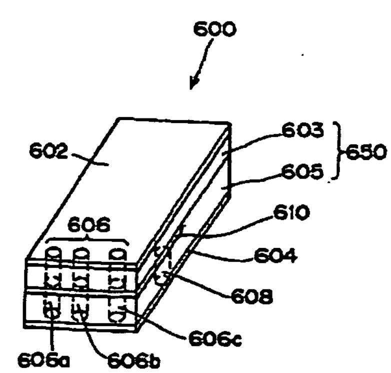


(A)　　　　(B)

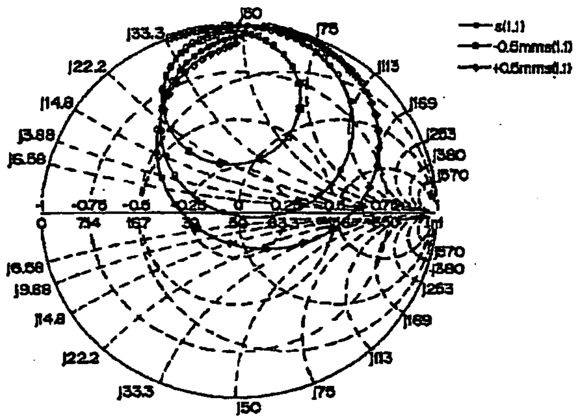
【図８】



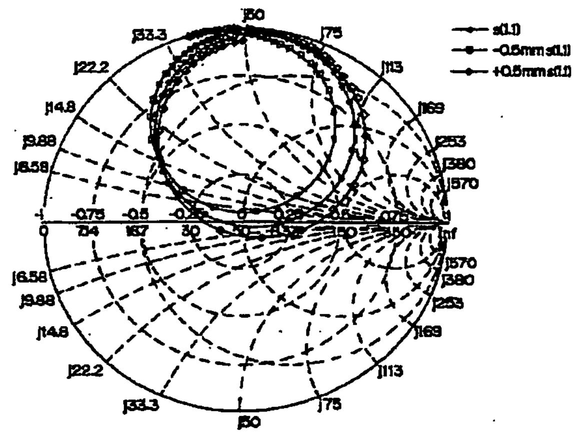
【図９】



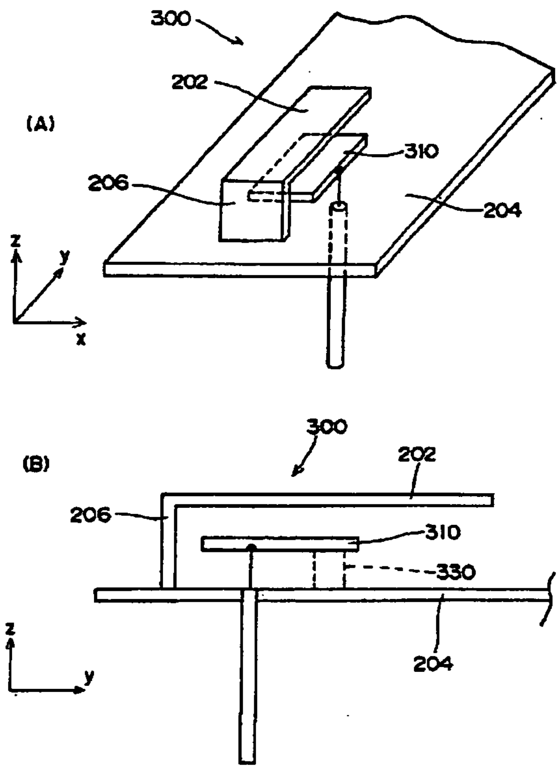
【図４】



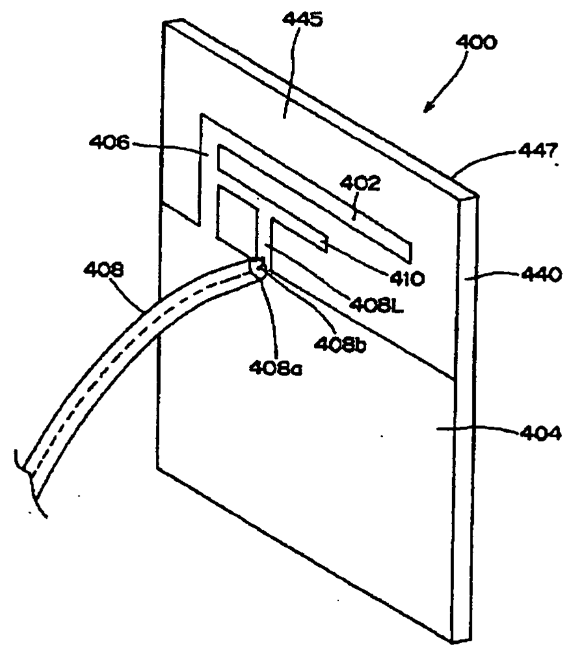
【図５】



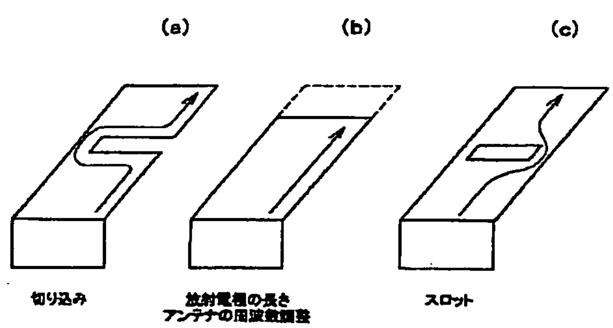
【図６】



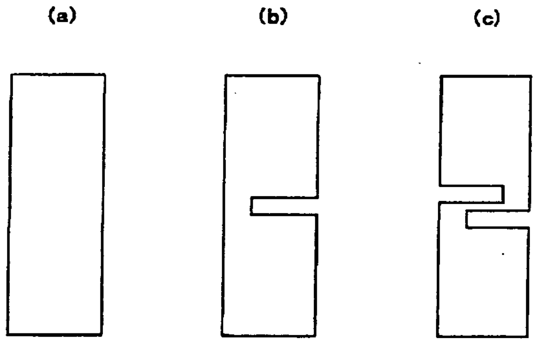
【図７】



【図１０】

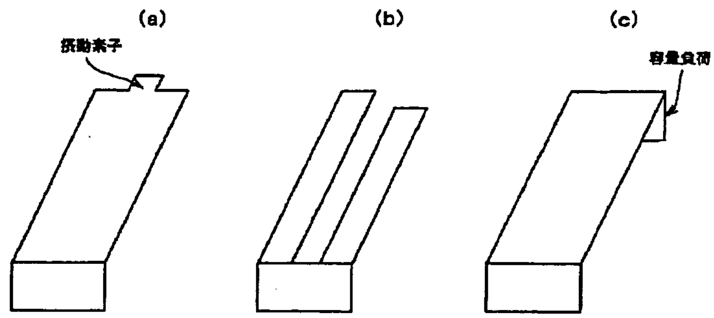


【図１１】



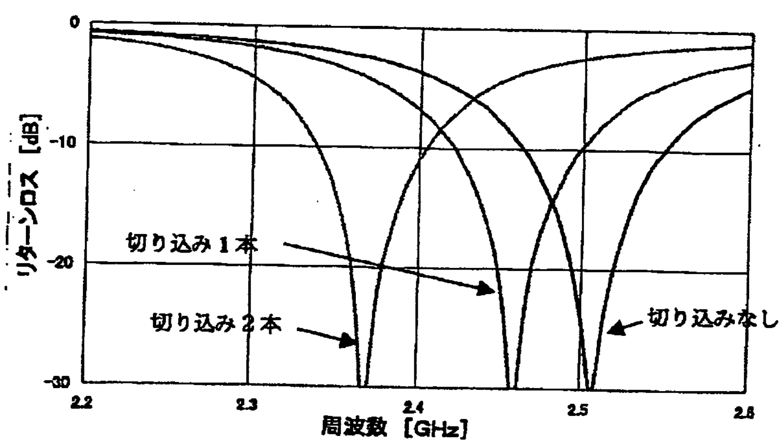
切り込み無　　　切り込み１本
放射電極周波数調整　　　切り込み2本

【図１３】



アンテナの多共振化、小型化

【図１２】



切込みによるアンテナのリターンロス変化